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TRANSACTIONS
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HIGH TEMPERATURE TREATMENTS OF CASTINGS AND FORGINGS AS EVIDENCED BY CORE DRILL TESTS FROM HEAVY SECTIONS

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Abstract

This paper discusses the results of investigations conducted primarily to determine correct thermal treatments for the improvement of grain structure of heavy section steel castings, so as to enable the designing engineer to make better use of this material than heretofore. It also includes a study of the limitations of the current practice of evaluating the physical properties of large steel castings and forgings from comparatively small coupon tests.

Experimental data supported by microscopical analysis of the complete and partial refinement respectively of grain structure of steel castings near surface and center of section is given and shows that considerably higher temperature, and extended soaking periods greater than "the current ones" are necessary for proper adjustment and alteration of grain structure to permit the use of higher service stresses in the design of large size electrical machinery. Suggestions for a recommended practice of heat treatment are given.

PROGRESS in foundry practice is quite often forced through aggressiveness of the designing engineer, desiring to make better use of the materials than has been done heretofore, in allowing for greater stresses. The present day foundry practice for evaluating the physical properties of steel castings of large cross-section and great weight from comparatively small coupon tests, usually gives higher test results than those from the body of the

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casting. The magnitude of these test values cannot, therefore, be made a basis of designs involving these higher stresses. The engineer consequently applies a generous safety factor.

The need for the development of a manufacturing process which results in uniform strength of large bodies of steel throughout and

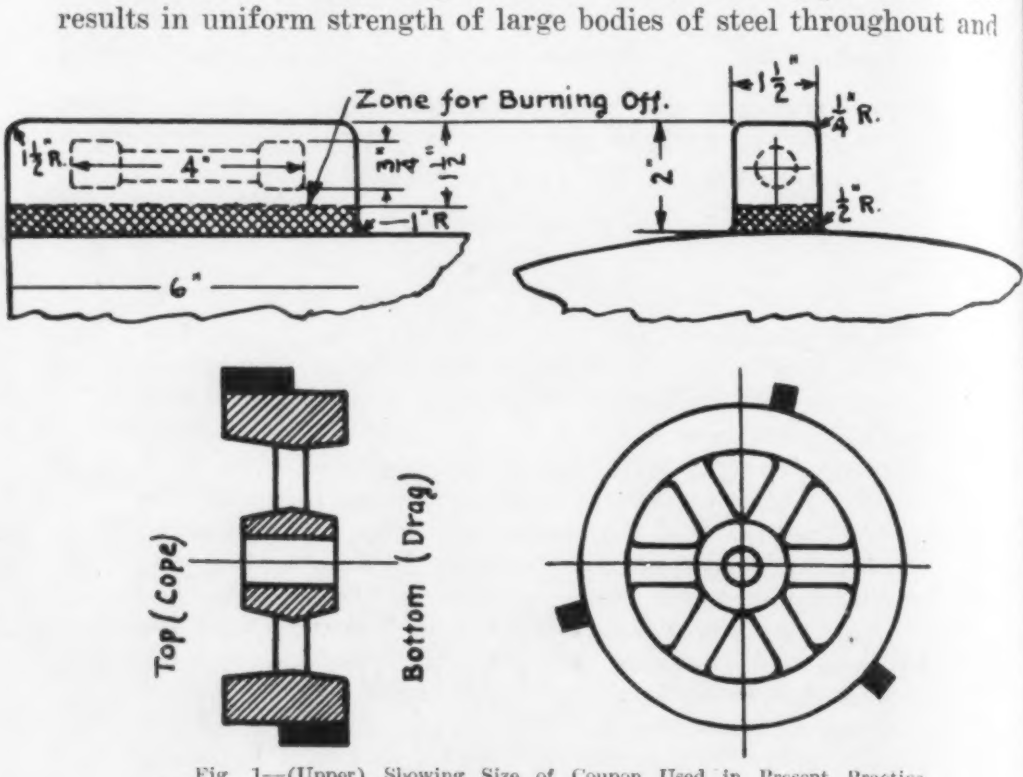


Fig. 1—(Upper) Showing Size of Coupon Used in Present Practice. (Lower) Showing the Number and Location of Coupons.

comparable with coupon test values is evident. It is common knowledge that coupon test values from castings of large cross-sections are often higher than values obtained from test bars taken from the body of the casting at critical locations or where slow freezing or solidification involves variation of structural composition due to low rate of diffusion relative to the rate of solidification, causing marked dendritic segregation. This is so wherever the coupon may be located, whether it is placed in the drag, the cope or at points where, due to the form or design of the casting, irregularity of crystallization from the rest of the body is expected and takes place. Fig. 1.

These variations of values between coupon tests and casting body tests are, of course, especially large in the "raw" or "as cast" condition, but persist to a lesser degree through and after the ordi-

nary heat treatment for annealing. These variations are of such a magnitude, that the differences in chemical composition, such as are encountered in all large bodies of cast metals do not account for them. Variation in chemical composition can, therefore, be responsible for only a small percentage of this difference. It will be shown, although it seems obvious, that the principal factor is the difference of physical structure between large section castings and small cross section coupons. However, elimination of this difference through alteration of structure by thermal treatment requires a range of temperature and involves a soaking at this temperature quite unusual when compared with ordinary annealing practice.

Structural Irregularity of the Casting as Compared with that of the Attached Coupon

A. *As Cast*—A microscopic analysis of the primary crystallization or solidification of the steel from the liquid state explains the structural irregularity through the cross section of the casting and difference between casting and coupon. The coupons are necessarily placed against the surface of the casting. Whether they are placed in the cope or in the drag is immaterial, because they cool faster than any other part of the casting except the sections thinner than the coupon. Naturally, the character of the dendritic filling of grain structure of the coupons is, chemically, much purer than the filling of the dendrites of the heavier sections and the more centrally located portions of the cross section of the casting. This chemical purity results in greater uniformity of freezing and produces a physical difference in structure from that of the body of the casting which aids and enhances physical properties especially ductility.

The physical or structural difference is enormously increased as the temperature falls and in extreme cases, the coupons may have cooled to a temperature of the gamma to alpha change temperature range, while formation of dendrites is still in progress at centrally located sections of massive castings.

Inherent impurities such as iron phosphide, iron sulphide, iron silicide, and iron carbide, have lower melting points than iron, and either do not or only slightly go into solid solution with iron and are, therefore, in the one case, segregated toward the

center of the mass while still liquid and in the latter case, deposit along the grain boundaries of the large crystals when solid. Grain boundary deposition of metalloids tend toward brittleness. The thickness of this film or deposit depends upon the size of crystal and is directly proportional to it, or stated differently, the smaller the grain, the less the percentage of deposits at grain boundaries, and the larger the grain, the larger the

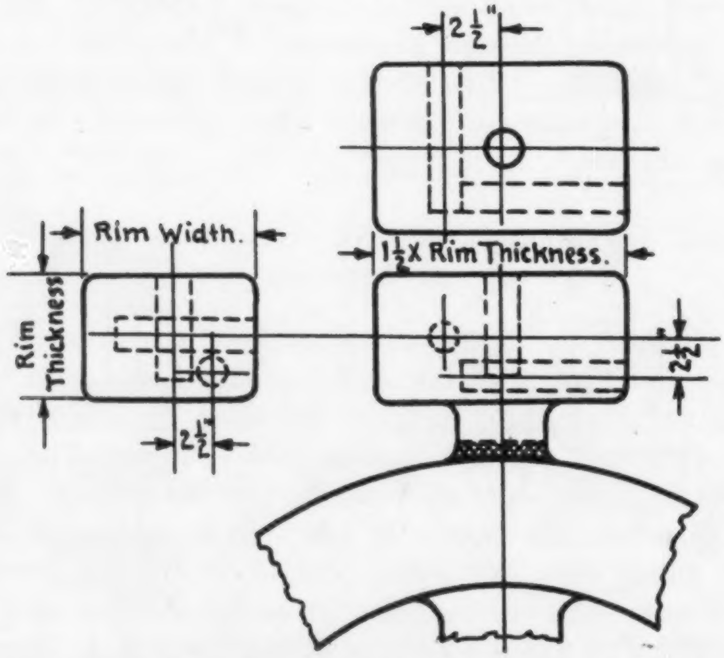


Fig. 2—Hollow Drill Tests—Recommended Practice. (For spiders above 40,000 lbs. weight use one test coupon for hollow drill tests. It shall be gated to the outside of rim with a substantial gate. Size of coupon to be the cross sectional size of the rim by one and one-half times the rim thickness for length. Take 3 tests from coupon located as per sketch above.)

percentage of boundary deposits with respect to surface area of crystal, which is, of course, self-evident from a consideration of increase of surface area on breaking up of a large crystal into a number of smaller ones.

B. *After Heat Treatment*—Reheating for annealing and normalizing again exposes and subjects the coupons to a grain refining heat for a considerable period of time while the centrally located section of the casting in most cases only reach this temperature and are not held there sufficiently long to break down, rearrange and refine the primary structure. Quite often the range of temperature used for annealing is not high enough to

effect the refinement. A striking example involving probably all the factors enumerated above is presented in a flywheel casting for a 6000-horsepower mill motor, details of which are given in Figs. 1, 2 and 3 and Table I. It shows of how little value the present practice of size and location of coupons are for tests to determine actual physical condition of such castings.

Additional evidence of these differences was obtained on gear center castings made of carbon-vanadium steel, Fig. 4. Exploration of the castings by core drill tests showed that core-drilled bars from sections 1 and 8, near cored wrist pin hole, are the critical locations where primary crystallization produces a columnar dendritic structure which persisted through the ordinarily employed heat treating processes for the annealing and normalizing of steel castings.

Table I

Coupon Tests

Test Bar Diameter	El. Limit Lbs. per Sq. In.	Yield Point Lbs. per Sq. In.	Ult. Strength Lbs. per Sq. In.	Elongation Per cent	Red. of Area Per cent
505	35000	38375	78800	31.8	48.
	*26000	36750	65625	7.2	10.4*
	36000	37875	78825	30.1	44.6
	37750	37875	77500	29.9	34.4
	28200	34800	70400	33.5	56.8
	26250	35125	72000	29.3	44.9
	29900	32650	69350	32.2	55.7
	27750	34500	71125	29.6	54.4
Core Drill Tests from Body of Rim					
505	34750	37175	73950	12.	18.8
375	23550	28000	79000	16.6	23.4
505	34250	37500	72125	10.4	15.2
505	37750	46875	72750	17.3	31.8

*Large gas pocket in section of test bar.

Table II gives values of core drill tests in which elongation and reduction of area are unsatisfactory.

The fracture of the broken specimens revealed irregularities which, while expected from the results, were unexpected with regard to their nature. Analysis of the unsatisfactory area showed silicon to be quite high (around 1 per cent), indicating probably aggregates of solid solution crystals of iron-vanadium

Table II
Core Drill Tests

El. Limit Lbs. per Sq. In.	Yield Point Lbs. per Sq. In.	Ult. Strength Lbs. per Sq. In.	Elong. Per cent	Red. of Area Per cent
34,750	37,175	73,950	12.	18.8
33,550	38,000	79,000	16.8	23.4
34,250	37,500	79,125	10.4	15.2
37,750	46,875	70,750	17.3	31.8

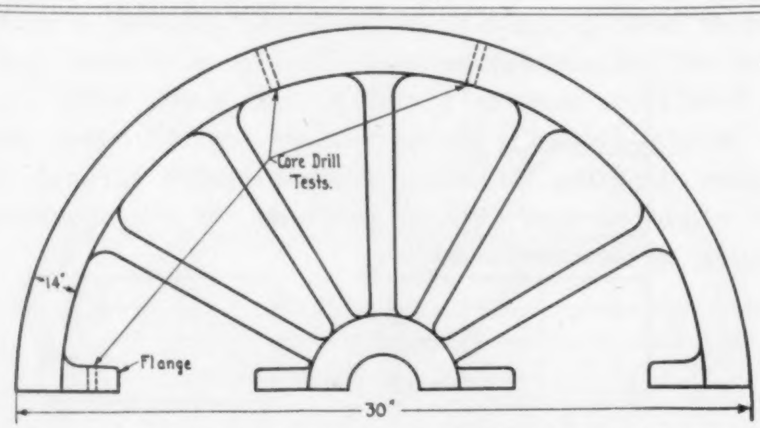


Fig. 3—Split Flywheel Casting, Showing Location of Core Drill Tests.

silicides in iron, which caused embrittling and lowering of ductility and defied diffusion by subsequent thermal treatments at temperatures ordinarily employed for annealing of steel castings in foundries. In the final analysis, this problem of producing satisfactory castings resolved itself into the following manufacturing practice and sequence.

(1) Production of a low silicon per cent in the melt consistent with a quiet, well-deoxidized heat of steel prior to making the alloy addition.

(2) Casting the steel into the mold as cold as is consistent with a production of the casting, or just hot enough to fill the mold well, and feed the casting to produce fairly rapid but uniform freezing.

(3) Subjecting the castings after solidification, but before being entirely cold, to a thermal treatment that will satisfactorily break up any dendritic segregations and at the same time, produce a grain refinement consistent with high strength and high ductility.

1. *Melting Practice Silicon Control*—To regulate the silicon content in a melt of steel on an acid bottom and consequently

under a blanket of a bisilicate slag requires skillful manipulation by the melter. Apparently best conditions prevail when the silicon content is below 0.08 per cent prior to making the alloy addition. It was also found advantageous to finish the melt very hot and recover the maximum percentage of residual silicon before alloying. A final silicon content below 0.20 per cent in the casting invariably gave the best properties.

2. *Molding Practice*—The foundry practice of gating and feeding of large castings are seriously involved to prevent shrink-

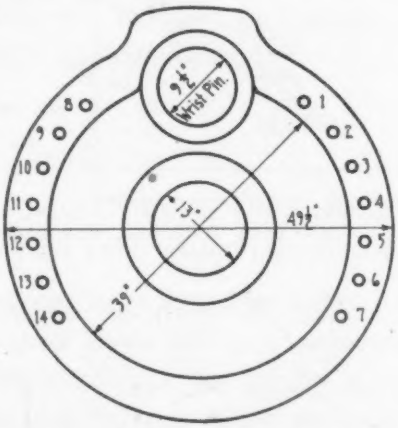


Fig. 4—Location of Core Drill Tests on Gear Center Casting.

age cavities and surface seams and cracks from irregular freezing and inverse segregation. The gating or mode of entry of the molten metal in the mold governs to a great extent, the degree and type of segregation in the castings and judicious location of risers is very important and aids materially in the production of uniformly sound castings.

3. *Heat Treating Practice*—(a) *Experimental Data*—The melting and molding practice has received practically the entire attention of foundrymen and it can safely be stated that a high degree of perfection is obtained in practically all recognized steel casting foundries. The heat treating practice of steel castings, however, still needs a great deal of attention and advancement to obtain maximum ductility coupled with sufficient strength for satisfactory performance under dynamic stress application in rotating parts of large size and high circumferential speed machines. A concentration of effort to improve the physical properties of large flywheel castings and rotating spiders so as

to uniformly and consistently meet the requirement, now obtained from bars machined from attached small size coupons, on core drill test bars from body of casting or test bars from center of full size prolongations, will certainly react favorably upon the

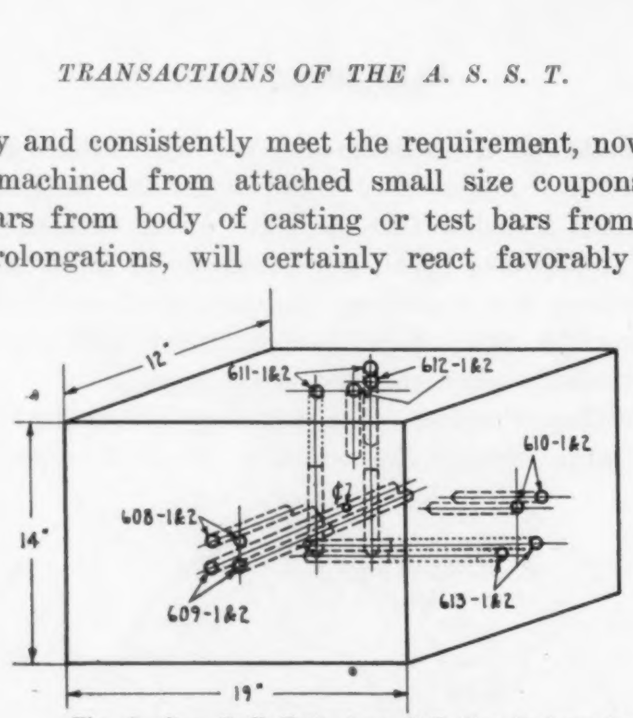


Fig. 5—Core Drill Tests from Full Size Prolongation Number 1 of Flywheel Casting.

more extensive application of large steel castings in high stressed parts of rotating machinery. The work and the experiments described extend over a period of approximately three years and was done in co-operation with one of the largest foundries in

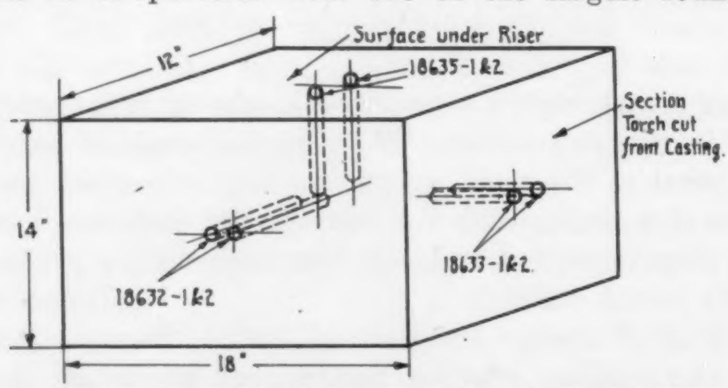


Fig. 6—Core Drill Tests from Full Size Prolongation Number 2 of Flywheel Casting.

this section of this country, on flywheel castings and spiders of 65,000 to 100,000 pounds in weight. At the present date, flywheel castings from this same plant do give test results on core drill test specimens from the body of the casting considerably in excess of our minimum requirements which are—

Yield Point Lbs. per Sq. In.	Ult. Strength Lbs. per Sq. In.	Elong. Per cent	Red. of Area Per cent
27,000	60,000	20	30

From our experience with gear center castings, Fig. 4, we naturally concluded that heat treating for refinement was carried on at too low a temperature to produce the desired results and to determine the correct heat treatment; a full size prolongation of the rim section of 18 inches in length, of a split flywheel was arranged for, core drill tests were taken after heat treatment of wheel casting at the foundry.

The check analysis of the first flywheel casting, Fig. 3, on which a full size prolongation was provided, was as follows:

	Per Cent
Carbon	0.25
Sulphur	0.034
Manganese	0.49
Silicon	0.30
Phosphorus	0.04

The heat treatment to which the casting had been subjected at the foundry was as follows:

Heat up to 1800 degrees Fahr. (982 degrees Cent.) in 30 hours,
hold at 1800 degrees Fahr. (982 degrees Cent.) for 36 hours,
cool to 1200 degrees Fahr. (650 degrees Cent.) in air.
Reheat to 1565 degrees Fahr. (850 degrees Cent.) in 18 hours,
hold at 1565 degrees Fahr. (850 degrees Cent.) for 20 hours,
cool to 400 degrees Fahr. (250 degrees Cent.) in furnace, then in air.

The full size prolongation was cast on each half. Hollow drill test on No. 1 prolongation gave the following results:

Yield Point	Ult. Strength	Elong.	Red. of Area
29,950	61,000	16%	25.8%

while attached small coupon tests gave the following results:

Table III
Coupon Test Values

Yield Point Lbs. per Sq. In.	Ult. Strength Lbs. per Sq. In.	Elong. Per cent	Red. of Area Per cent
37,700	69,900	28	41.9 Cope
42,900	72,400	31	50.6 Drag
34,950	69,400	31	50.6 Cope
44,300	71,400	31	52.0 Drag

The full size prolongations were then cut from the casting and given the following heat treatment:

Heated to 2012 degrees Fahr. (1100 degrees Cent.) in 12 hours,
held at 2012 degrees Fahr. (1100 degrees Cent.) for 6 hours,
cooled in air to black heat.
Reheated to 1580 degrees Fahr. in 11 hours,
held at 1580 degrees Fahr. for 6 hours,
cooled in air to approximately 600 degrees Fahr.
Reheated to 1275 degrees Fahr. (690 degrees Cent.) in 9-½ hours,
held at 1275 degrees Fahr. (690 degrees Cent.) for 5 hours,
cooled in furnace.

The time periods of holding the casting prolongations at the respective temperatures was shorter than would have been necessary on a green casting, the previous treatments made a cut in time permissible. The treatment agreed upon and found to give results, requires 2 hours' soaking at heat for every inch of width of cross section. Core drill specimens taken from prolongation block as shown in Fig. 5, gave the results shown in Tables IV and IVa.

Table IV
Core Drill Test Values from Full Size Prolongation I, taken from Surface to 5 Inch Depth (Fig. 5)

Serial No.	El. Limit Lbs. per Sq. In.	Yield Point Lbs. per Sq. In.	Ult. Strength Lbs. per Sq. In.	Elong. Per cent	Red. of Area Per cent
18608-1	27,500	33,125	66,500	28.1	45.4
18608-2	31,500	34,250	66,875	27.9	37.3
18610-1	28,750	34,125	66,500	25.2	41.6
18610-2	29,000	34,250	65,250	22.3	36.3
18612-1	28,500	33,750	66,875	29.2	47.5
18612-2	26,750	33,500	65,875	27.8	44.0

Table IV (a)
Core Drill Test Value of Bars taken from Center of Full Size Prolongation I (Fig. 5)

Serial No.	El. Limit	Yield Point	Ult. Strength	Elong.	Red. of Area
18609-1	27,750	32,750	66,250	28.5	44.9
18609-2	30,750	33,375	66,275	24.1	31.8
18611-1	30,625	33,625	66,275	10.4*	12.3*
18611-2	31,250	33,625	65,750	25.4	36.0
18613-1	31,000	32,625	65,375	25.7	37.3
18613-2	30,125	32,875	66,250	25.3	40.7

*Broke in shoulder outside of gauge mark.

The heat treatment of the second prolongation was identically that given prolongation I, and the test results of specimens taken as shown in Fig. 6 are given in Table V. The center section could not be taken on account of a shrinkage cavity, which was exposed by slotting through the block, the recurrence of this cavity, in later castings, has been satisfactorily eliminated by adjusting position and form of riser.

Table V

Core Drill Tests Values from Full Size Prolongation V taken from Surface to 5 Inch Depth (Fig. 6)

Serial No.	El. Limit Lbs. per Sq. In.	Yield Point Lbs. per Sq. In.	Ult, Strength Lbs. per Sq. In.	Elong. Per cent	Red. of Area Per cent
18632-1	21,300	26,900	59,700	33.	56.6
18632-2	23,375	25,900	59,800	31.8	53.1
18633-1	19,925	26,700	59,100	33.4	50.4
18633-2	20,850	26,300	59,150	35.0	51.9
18635-1	24,250	28,125	59,375	36.8	59.8
18635-2	23,875	28,900	59,800	34.8	56.6

It is evident from an analysis of the test results and a comparison with those obtained from previous thermal treatments, that the uniformity of refinement is practically complete and also that a temperature of 2012 degrees Fahr. (1100 degrees Cent.) during the first heating cycle is required to bring about these results. The sluggishness and resistance of the structural components to diffuse properly is responsible for this lack of response. It requires higher temperatures and longer exposure as evidenced by result after sufficient soaking time period at high heat.

The importance of holding the castings sufficiently long at high temperature was forcefully brought out quite recently by a set of half spider castings having a weight of approximately 70,000 pounds each on which the time period of holding at 2012 degrees Fahr. (1100 degrees Cent.) was shortened to meet a delivery date promised. These castings had a full rim section sized coupon gated to it for core drill test in accordance with Fig. 6. The results of these tests are given in Table VI and are entirely unsatisfactory. Photomicrographs Figs. 7, 8, 9, 10 and 11 are from small size coupons as cast and after annealing.

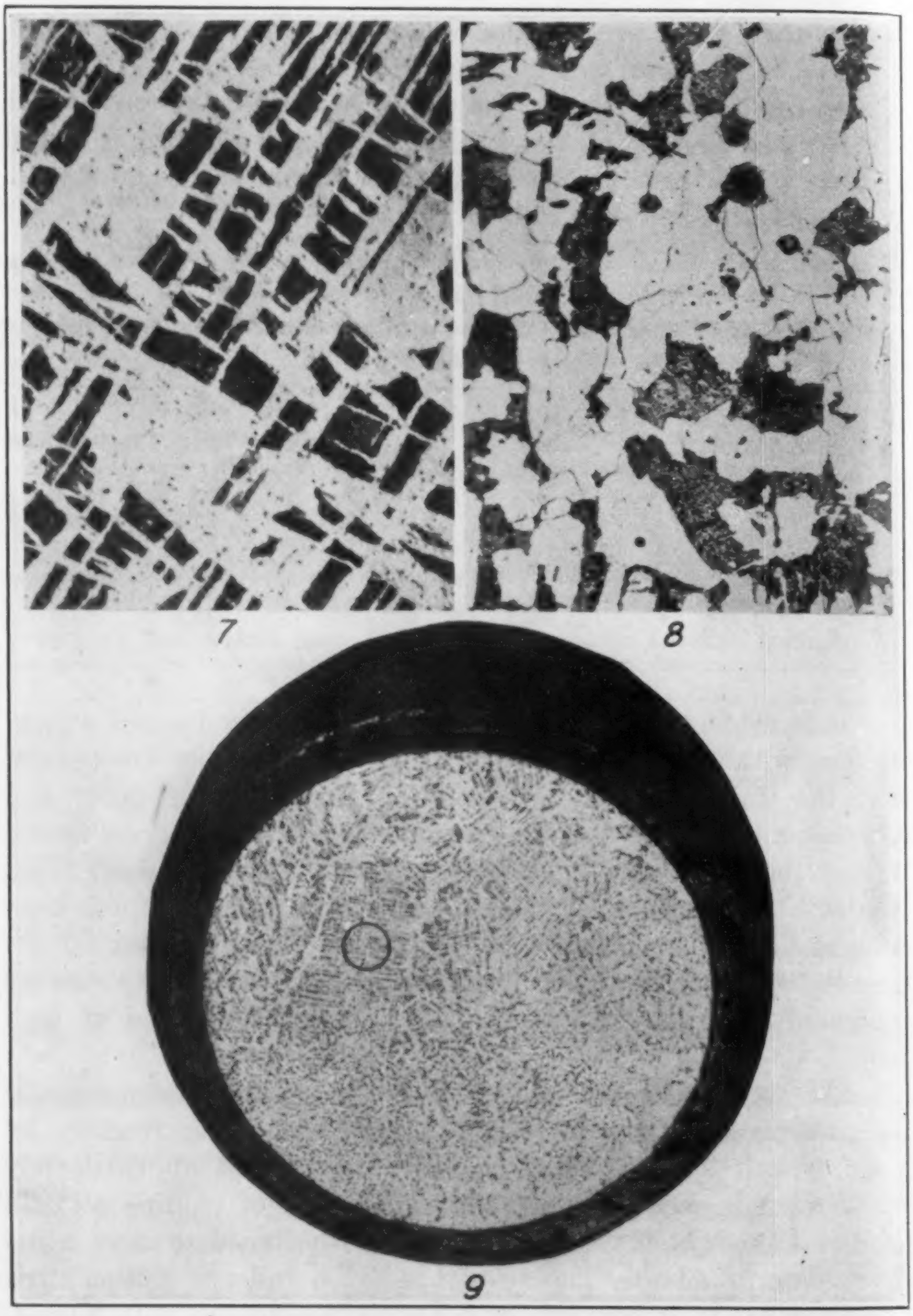


Fig. 7—Small Size Coupon as Cast. Note Widmanstätten Structure. 50 x. Fig. 8—Photomicrograph of Coupon Annealed at Normalizing Temperature of 1700 Degrees Fahr. 100 x. Fig. 9—Coupon 3.5 Inches Diameter. Note the Large Crystals and Fully Developed Widmanstätten Lines Indicating Long Exposure to High Temperature.

Table VI

Core Drill Tests (Fig. 6)

	El. Limit Lbs. per Sq. In.	Yield Point Lbs. per Sq. In.	Ult. Strength Lbs. per Sq. In.	Elong. Per cent	Red. of Area Per cent
A *	30,800	33,300	65,800	8.2	10.7
A-1	29,000	33,375	66,000	9.3	18.7
A-2	33,000	38,500	76,250	10.3	16.7
X		31,580	67,640	28.5	38.5
Y		34,160	68,260	26.0	36.0
Z	31,500	40,000	79,875	18.0	19.2

The microstructures (Figs. 12 to 16) of the castings at center of rim are illustrative of the changes after the various thermal treatments, (A-1-5), (A-2-6), (X-7), (Y-8) and (Z-9) and show that heating for proper length of time at high enough temperature will produce a microstructure consistent with physical values with regard to strength and ductility, rarely exceeded in annealed large forgings.

The thermal treatment finally recommended and used with entire success is as follows:

Heat castings slowly and uniformly under atmospheric condition that will cause minimum scaling to 2012 degrees Fahr. (1100 degrees Cent.), 1½ hours per inch of minimum dimension of the heaviest section is approximately the minimum time to reach that temperature. Hold at this temperature for at least 2 hours per inch of width of cross section.

Cool in furnace with door open to 1600 degrees Fahr., then in air to black heat of 800 degrees Fahr.

Reheat to 1600 degrees Fahr., time of heating to consume about 1 hour for every inch of width of cross section.

Hold at 1600 degrees Fahr. one hour for every inch of width of cross section. Cool in air to black heat (800 degrees Fahr.).

Reheat to 1275 degrees Fahr. and cool in furnace to 600 degrees Fahr., then in air.

Summary

Summarizing the results it has been shown that—

(1) The grain structure of large section carbon steel castings is not uniformly refined at the relatively low temperature annealing treatment ordinarily employed in steel foundries.

(2) Complete refinement does take place at considerably higher temperature and a steel casting of uniformly high strength and high ductility, is produced.

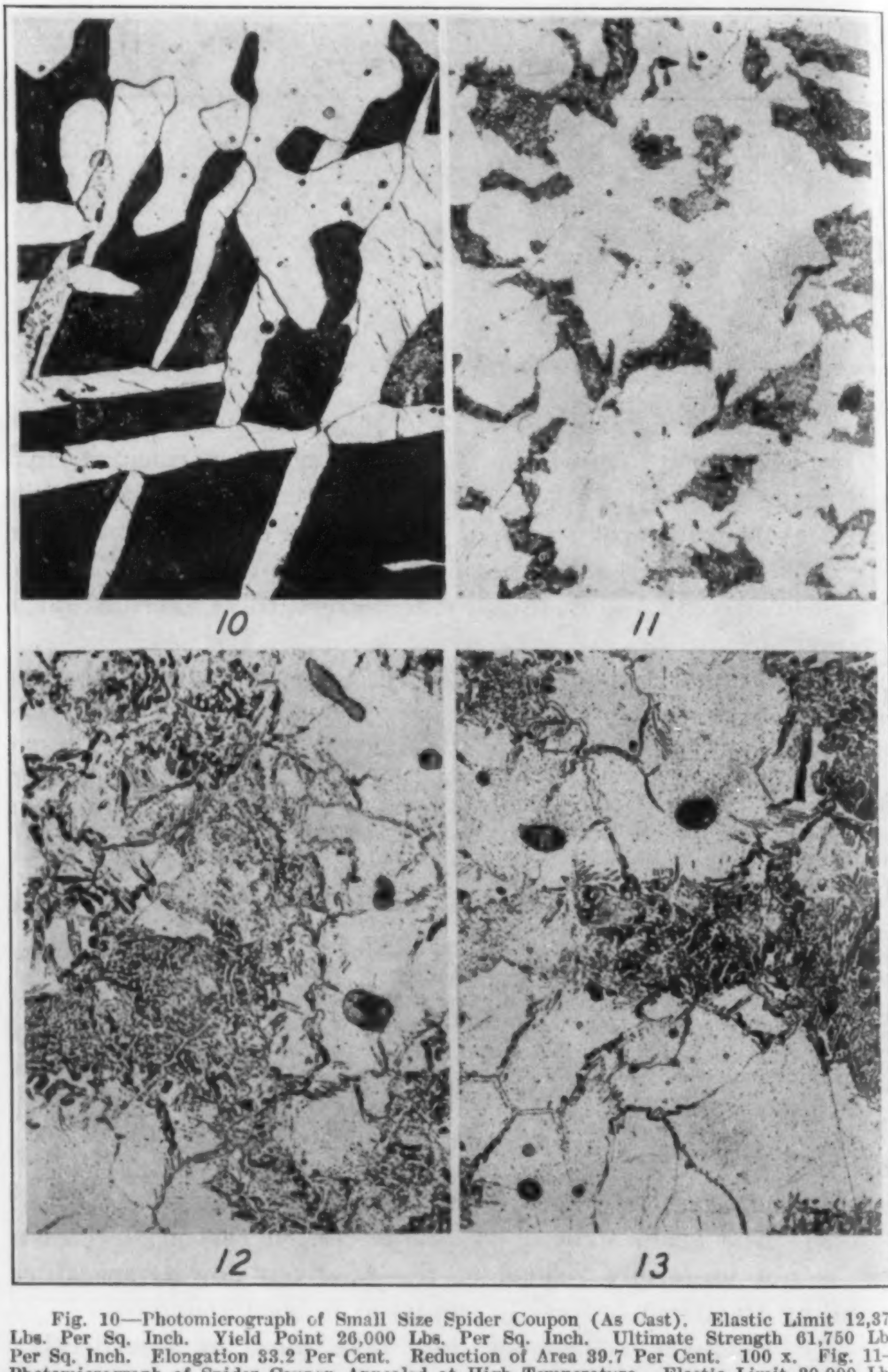


Fig. 10—Photomicrograph of Small Size Spider Coupon (As Cast). Elastic Limit 12,375 Lbs. Per Sq. Inch. Yield Point 26,000 Lbs. Per Sq. Inch. Ultimate Strength 61,750 Lbs. Per Sq. Inch. Elongation 33.2 Per Cent. Reduction of Area 39.7 Per Cent. 100 x. Fig. 11—Photomicrograph of Spider Coupon Annealed at High Temperature. Elastic Limit 30,000 Lbs. Per Sq. Inch. Yield Point 38,000 Lbs. Per Sq. Inch. Ultimate Strength 72,000 Lbs. Per Sq. Inch. Elongation 26 Per Cent, Reduction of Area 50 Per Cent. 100 x.

Fig. 12—Photomicrograph of Sample from the Rim of Casting After Heat Treatment at the Foundry in Which Time of Soaking was Too Short. 100 x. Fig. 13—Photomicrograph of Sample Taken from the Rim of the Other Half. Treated as Sample of Fig. 12. 100 x.

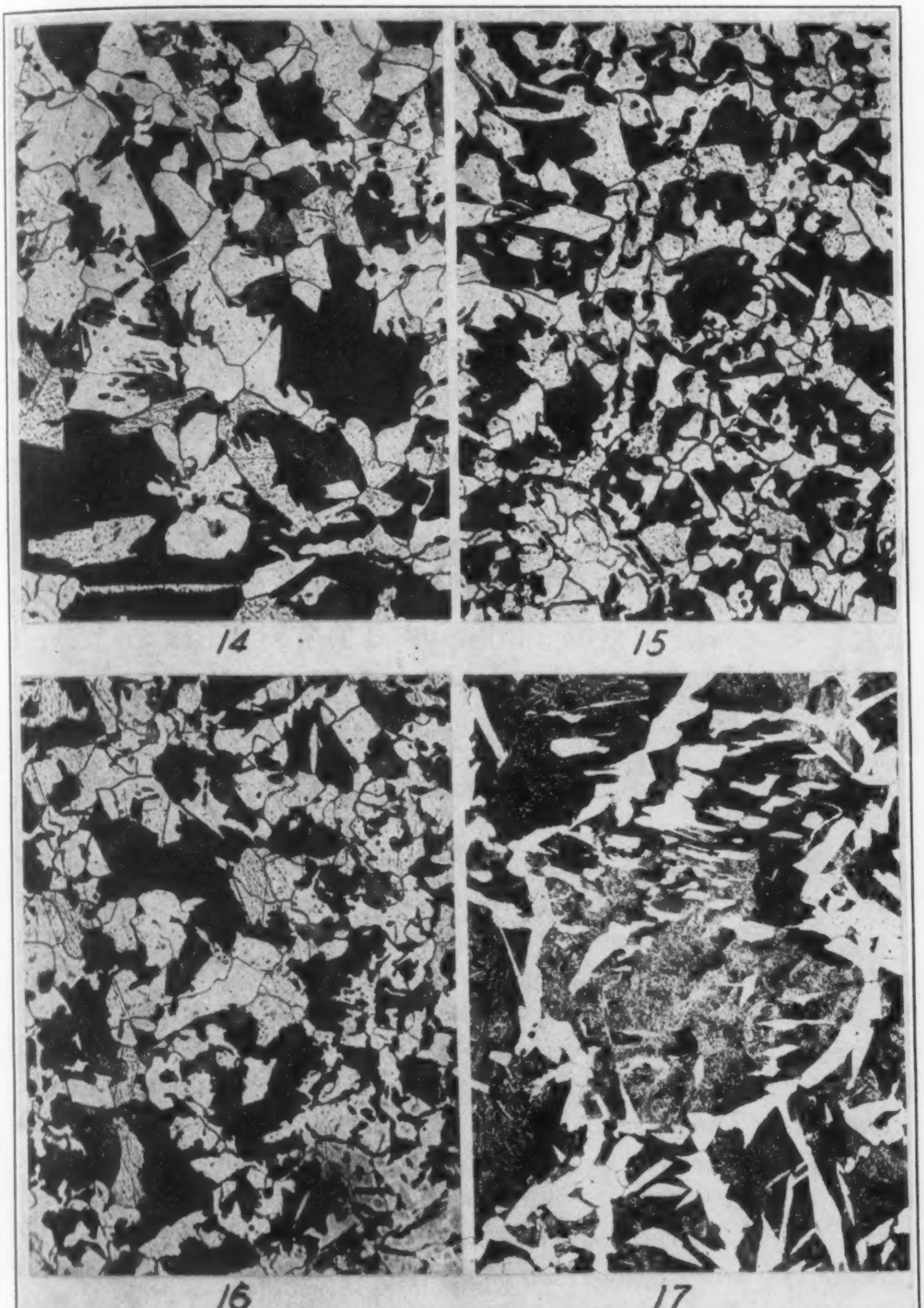


Fig. 14—Photomicrograph of Sample Taken from the Flange of Spider Casting After Heat Treatment. 100 x. Fig. 15—Photomicrograph of Sample from the Rim of Same Casting as Fig. 14. After Retreatment. 100 x. Fig. 16—Photomicrograph of Sample Taken from the Rim of the Other Half of the Spider After Retreatment. This Sample is from the Cold Part of the Furnace. 100 x. Fig. 17—Photomicrograph of Sample from the Center of a Forging. (As Forged.) 0.44 Per Cent Carbon. 100 x.

(3) It is very evident that our present practice of evaluating characteristics of steel castings from small coupon tests, does not give the properties of the casting in heavy and critical sections, and should be replaced by core drill tests from body of castings wherever possible, and if this cannot be done, the dimensions of the coupons should be equivalent to the heaviest or critical section of the casting. This full size coupon must be heat treated integral with the casting if it is to be representative of the physical properties of the casting.

(4) Core drill tests from center sections of large castings can meet the values specified and usually only met by coupon tests providing high temperature treatment for breaking up of cast structure is employed, which minimum temperature is 2000 degrees Fahr. (1100 degrees Cent.) for ordinary carbon steel castings.

PART II

HEAT TREATMENT OF LARGE FORGINGS AS EVIDENCED BY CORE DRILL TESTS FROM CENTRALLY LOCATED SECTIONS

Evaluation of physical characteristics of large bodies of steel by surface test bars is not confined to steel foundry castings. It is equally as often met in forge plants and the same reluctance to employ high enough temperatures for complete and uniform refinement of structure after forging is here encountered. Obviously the situation is much more serious, since forgings are almost exclusively used in service where high stresses are involved and any unsatisfactory structural conditions are bound to cause serious difficulties. Although the brittleness and metallurgical weakness in forgings is sometimes produced by grain enlargement and is grain growth brittleness, and may not be weakness and brittleness due to dendritic segregation. It is, nevertheless, a dangerous and unsatisfactory condition for which heat treatment at elevated temperature and for sufficient length of time, is the only remedy. The writer is completely convinced that for satisfactory grain refinement, it is necessary to heat forgings of large sections above the forging finishing temperature, which is then followed by a normalizing treatment and finally by a strain relieving anneal. A description of some interesting experiments illustrating this, is given below. The forgings were

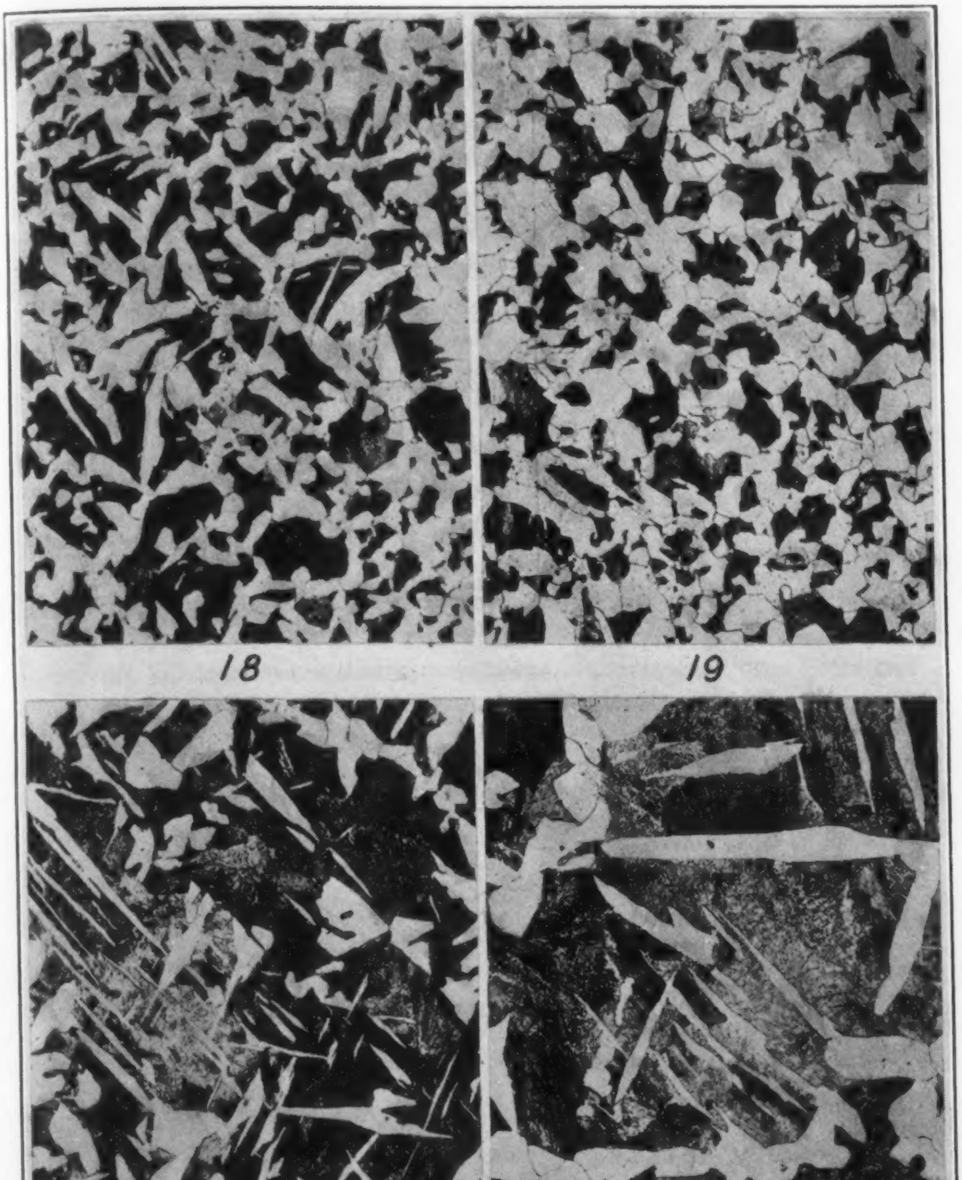


Fig. 18—Photomicrograph of Disk Forging After 2200 Degrees Fahr. Refining Heat, Sample Taken from Center of Disk. 100 x. Fig. 19—Photomicrograph of Disk Forging After Reheating for Normalizing. Sample Taken from Center of Disk. Fig. 20—Photomicrograph of Sample Taken from the Center of Radial Bar. Forging After Normalizing Heat of 1700 Degrees Fahr. Note Coarse Structure is Retained. Fig. 21—Photomicrograph of Sample from Disk as Forged. 0.35 Per Cent Carbon.

disks 52 inches in diameter and 8 inches thick weighing about 6000 pounds made from a basic open-hearth ingot of approximate analysis of—

	Per Cent
Carbon	0.44
Manganese	0.57
Phosphorus	0.013
Sulphur	0.032
Silicon	0.23

Figs. 22 and 23 give the general dimension of ingot and resulting disk. The ingot slug was first squashed to within close

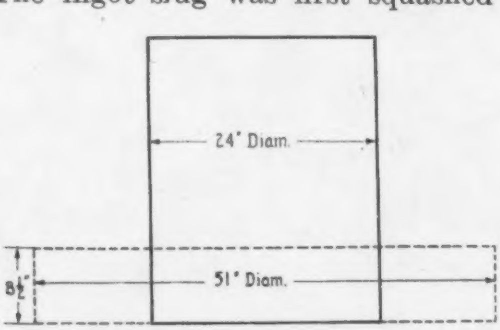


Fig. 22—Ingot Slug and Pressed Disk.

dimensional thickness under a hydraulic press and then edges squared and finished in a tire mill. The core drill test bars were then taken as shown in Fig. 24, the resultant values are given in Table VII, and show that the physical condition of the disk is

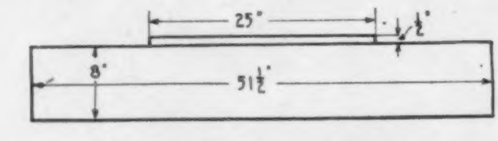


Fig. 23—Finished Rolled Disk.

fairly good at and near the surface, but is entirely unsatisfactory in deeper seated locations.

A normalizing treatment at 1700 degrees Fahr. (925 degrees Cent.) left the structural characteristics unsatisfactory for high physical strength and good ductility, although the improvement in the surface layer is marked; but the centrally located sections are still low in elastic values and low in ductility as shown in Table VIII. Fig. 25 shows location from which test bars were taken. See also photomicrographs Figs. 17, 20 and 21.

A disk was then heated to 2200 degrees Fahr. (1200 degrees Cent.) and held for 12 hours at this heat and cooled in furnace

Table VII

Disc Forging (as Forged). Location of Core Drill Test Bars Shown in Fig. 24

Serial No.	Location	Elastic Limit Lbs. per sq. inch	Yield Point per sq. inch	Tensile Strength per sq. inch	Elong. % in 2"	% Red. of Area
29782	Tang. 12-½" at surface	25,000	*	88,625	24.8	39.1
29783	Tang. 12-½" at center	27,500		90,375	10.1	12.6
29784	Tang. near circum. at surface	20,000		90,750	24.3	38.8
29785	Tang. near circum. at center	21,500		90,750	22.7	38.8
29786	Axial 12-½"	26,750		71,375	2.5	5.5
29787	Radial 12-½" at surface	24,000		87,250	11.2	15.9
29788	Radial 12-½" at center	26,500		85,375	9.2	11.9
29797	Radial near circum. at center	29,875		91,125	12.0	20.6

*No drop of beam.

Table VIII

Disc Forging after Normalizing Treatment. Location of Core Drill Test Bars are Shown in Fig. 25

Serial No.	Location	Elastic Limit Lbs. per sq. inch	Yield Point per sq. inch	Tensile Strength per sq. inch	Elong. % in 2"	% Red. of Area
29789	Tang. 12-½" in surface	37,500	40,500	82,500	23.6	38.2
29790	Tang. 12-½" in center	30,250	36,125	78,125	20.8	26.1
29791	Tang. near circum. surface	26,125	40,125	85,000	26.5	40.4
29792	Tang. near circum. center	41,000	42,875	86,375	25.3	40.7
29793	Axial 12-½"	25,500	34,000	54,000	3.2	8.1
29794	Radial 12-½" in surface	33,250	36,750	80,000	28.5	39.4
29795	Radial 12-½" in center	34,000	37,875	76,125	17.3	20.9
29796	Radial near circum. center	37,000	39,875	84,750	22.5	27.8

to 1700 degrees Fahr., then cooled in air after which radial test bars were taken from center of disk. The disk was then reheated to 1650 degrees Fahr. (875 degrees Cent.) and held for 8 hours, air cooled and another radial test bar taken from center section. The results of the tests are given in Table IX and photomicrographs Figs. 18 and 19, and show a satisfactory refinement in center portion of forging.

A reheat at 1250 degrees Fahr. for relieving of strains introduced during air cooling usually follows the normalizing treatment and ordinarily raises the ductility slightly but does affect the elastic limit very little, it was omitted in this experimental

test since the results we were after, the refinement of structure of forging at center, was definitely accomplished.

These results have been duplicated consistently, obviously smaller size forgings receiving a generous amount of hot work

Table IX
Radial Core Drill Tests from Center of Disk

	El. Limit Lbs. per sq. in.	Yield Point Lbs. per sq. in.	Ult. Strength Lbs. per sq. in.	Elong. Per cent	Red. Area Per cent
As Received	27,250	46,000	88,750	3.8	8.1
After normalizing at 1700°F. (925°C)	24,375	48,200	91,400	8.8	10.
After High Heat of 1200°C. (2200°F)	26,000	36,750	81,625	22.7	27.5
Normalized after high heat	40,250	46,000	90,250	20.2	36.3

Fig. 24—Disk Forging (As Forged), Showing Location of Core Drill Test Bars.

Fig. 25—Disk Forging (After Normalizing), Showing Location of Core Drill Test Bars, Also Cuts Through Disk for Examination of Soundness of Steel.

are not structurally as weak as large forgings of which the centrally located sections receive practically no work at all. These large forgings are, therefore, to be considered equally as weak physically as castings, and refinement cannot be expected at ordinary forge shop annealing and normalizing temperatures, although it is the author's contention that a considerably more uniform and complete refinement can be brought about by employing a preliminary high temperature refining heat to all forgings whatever their physical dimensions may be before actual heat treatment for specified physical requirements is undertaken. Thermal refinements of grain structure of finished forgings is always uniformly satisfactory and complete if done above the finish forging temperature.

Conclusion

In concluding, attention is again called to the most important fact brought out in the investigation, namely, that higher stresses are permissible in large steel cast and forged parts of machinery, than have been used heretofore, without reducing the factor of safety, providing high temperature treatments are employed for complete and uniform refinement of grain structure.

The co-operation of the steel foundries and steel mills at which these practices are now followed was gratifying indeed and the results obtained are pointed to by them as an outstanding achievement in foundry practice and constitutes the starting point for standardization of heat treatment of steel castings and forgings and the evaluation of physical characteristics from core drill body tests or tests from full section sized coupons on which direct values for design purpose can be obtained. In closing I wish to express my appreciation to Mr. O. W. Ellis and Miss Ferguson of the metallurgical section of the Westinghouse Research Laboratory for the splendid cooperation in the preparation of the photomicrographs, also to all those who have been of assistance in the conductance of the experiments and the development work.

DISCUSSION

Written Discussion: By R. A. Bull of the Electrical Steel Founders Research Group, Chicago.

Those who make steel castings are highly pleased to observe manifestations such as Mr. Merten shows in his paper, of the keen constructive interest in the product of the steel foundry taken by metallurgists serving consumers. Only

by close co-operation between maker and user can the satisfactory or unsatisfactory history of many steel castings be traced and recorded, for the ultimate benefit of all concerned.

The author presents evidence entitled to very serious consideration, tending to show that a temperature higher than that characterizing ordinary normalizing and other annealing operations in the steel foundry effects changes that have probably not been suspected by many. I believe that other persons have obtained somewhat similar results, but have not published them. It is hoped that these experiments will be supplemented by tests of other investigators so as to very definitely determine what may be expected in the annealing of large section steel castings at high temperatures for periods of time found necessary to yield the best results.

It is a matter of regret to me that I am unable to contribute data on this interesting question. This is primarily because my professional activities have been centered, commercially, for a considerable period in the manufacture, including heat treatment, of small and medium sized steel castings, where the problem of mass in annealing individual pieces is not involved seriously.

It was not essential for the purpose of Mr. Merten's paper, that he should have pointed out one important factor to which he did not refer, and which I take this opportunity to emphasize, because of my conviction that the kind of desirable co-operation previously mentioned may be materially improved.

If it is subsequently conceded that a temperature some 400 degrees Fahr., higher than that found very satisfactory for steel castings of moderate sections is necessary to refine the structure and to develop the desired physical properties, what will happen when treating at the high temperature, steel castings whose members, differing widely as to uniformity of section, include those of relatively small thickness? I presume no one will dispute the statement that overheating a section of cast steel of average size does considerable harm. We are familiar with the similarity of structures typical of an underheated and an over-heated casting. The solution of the problem, insofar as it may be solved rightly, rests in the hands of the designer. It will be solved more often and more satisfactorily if members of this society vigorously exert their influence to reduce to the greatest possible extent the inequalities of sections in steel parts to be heat treated.

Numerous steel casting designs are known to the foundryman to be metallurgically wrong. He is sometimes expected to display ingenuity in many details of manufacture, which would defy natural laws. It is natural that I should think he generally does a pretty fair job, considering his handicaps. But he cannot put into his product all those excellent characteristics it is capable of developing, and which it is to the makers' interest to produce, if the users of the product do not or cannot help themselves in the matter of skilfull design.

In discussing the structural irregularity of the casting as compared with that of the attached coupon, the author states that "the character of the dendritic filling of grain structure of the coupons is chemically much purer than the filling of the dendrites of the heavier sections and the more centrally located portions of the cross-section of the casting." While the meaning of the author seems clear to those familiar with the subject, it may not

be out of place to point out that a dendritic structure as ordinarily understood does not characterize a test coupon such as is referred to in this statement by Mr. Merten. Indeed, it is a valuable feature of steel castings having small and medium-sized sections that they are free from dendritic structures, which often present serious difficulties in the attempts to change them.

The author, in his description of the satisfactory production of castings used for his tests, refers to the advantage of a low silicon content in the melt consistent with a quite well deoxidized heat prior to making the alloy addition. This may be regarded as an incorrect statement by some who associate high silicon content with necessary deoxidation. Many familiar with steel making know that one may have a wild heat with a high percentage of silicon; and that a quiet heat may be produced with a low silicon content, favored by Mr. Merten.

Further, with reference to the silicon content, Mr. Merten states that a final proportion below 0.20 per cent in the castings invariably gave the best properties. There is no disposition to question the results quoted by the experimenter when making the statement. If the castings used for the tests showed the best physical properties when the silicon was below 0.20 per cent in the finished material, I believe the reason was not this relatively low silicon content. It must have been a coincidence, which could easily happen. There are far too many instances of excellent physical properties in heat-treated small and large steel castings containing more than 0.20 per cent silicon to allow an indirect argument for low silicon to stand unchallenged.

A former president of this Society, in a paper* presented before the American Society of Mechanical Engineers, and elsewhere has contended for a silicon content in steel castings never less than 0.20 per cent. In contrast comes now another metallurgist prominent in this Society, apparently favoring at least for heavy section steel castings, a silicon content below 0.20 per cent. As a matter of fact the content of silicon or that of any other element (possibly barring phosphorus and sulphur), should never be considered except with respect to the percentages of all other elements in the metal. Furthermore, the percentage of silicon may be found high or low, depending on many other conditions, both in excellent steel and in very poor steel.

It is not surprising that metallurgists representing consumers differ in their opinions regarding desirable chemical compositions. Necessarily their views are the results of their individual experiences. The same might be claimed for the opinion of steel foundrymen. But the latter class consists of men whose study of varying compositions and the physical properties resulting from them necessarily is more intensive and comprehensive than can characterize the consideration given such matters by metallurgists whose daily activities are not associated closely with the production of the metal.

If Mr. Merten and others have developed a method of heat treatment that will yield thoroughly satisfactory physical results in the heart of a heavy section of steel, cast or rolled or forged, these gentlemen are to be warmly congratulated. The thanks of producers and consumers are due Mr. Merten for contributing such valuable data as are given in his paper.

Written Discussion: By G. M. Eaton, Molybdenum Corporation

*"Heat Treatment Data on Quality Steel Castings"—A. E. White, Nov. 30-Dec. 4, 1925.

of America, Pittsburgh. Just a few words as to the purpose of this testing. It is to find out whether this large casting or forging will do the work for which it is designed. This means that no regular rule can be made for the location of these hollow-drill tests, they must be placed, particularly in forgings, in the location and the direction of the stress, and there should be the strongest opposition to any attempt to generalize in cases where problems are fundamentally individual.

One other point that we must guard against is that some development is going to be necessary in determining broadly over the large parts involved just what can be secured in the critical locations, and I urge tolerance on the part of the designer and a willingness, perhaps, to accept in the buried locations something a little lower than he may wish, if that is the best that he can get, until this development has been ironed out by prolonged experience.

The writer has chafed for years at the practice of relying upon coupon tests for evaluating the physical characteristics of large castings and forgings.

The designer is entirely at sea when this practice is followed and he has only a factor of ignorance between his machine and trouble.

It is not so long ago that it was current practice in many foundries to place the coupons on large castings where they represented only the very best conditions that it was possible to secure for the coupon. Sometimes it required a lot of persuasion to have coupons placed so that they represented the worst possible conditions. Yet in many cases, this was the sensible course.

With the adoption of high temperature treatments and hollow drill tests as outlined by Mr. Merten it becomes possible to adopt factors of safety with considerable assurance that they are more representative than coupon tests. The designer is still faced with the fact that the existence of draw holes must be suspected and allowed for, but it is a real advance in the art to give to the designer and operator reliable information as to the physical characteristics of the metal that is actually present in his large structural parts.

In fairness to the foundries and forge shops, the designer and the metallurgical engineer must bear in mind that some development is involved in learning broadly just what hollow-drill test results can be secured, and occasions will probably arise when it will be necessary to modify the specifiations which have been evolved on the basis of coupon tests. But it is much more satisfactory to call for 25 per cent elongation and 45 per cent reduction of area and really secure these values than it is to call for higher values and actually have them only in favorable surface locations, while the characteristics of parts more deeply buried in the body of the piece remain quite indeterminate.

In the case of large forgings it is often possible for the designer to assist the steel mill by calling for the highest hollow-drill test results only in the directions where the exigencies of service require them. In doing this he will also help himself as there is bound to be an ultimate reflection of his co-operative effort in the price of his raw material.

Written Discussion: By Harold J. Stein, Allis-Chalmers Manufacturing Company, Milwaukee.

Harold J. Stein: I wish to preface my discussion of Mr. Merten's valuable paper in stating that the discussion that I have written here is based on

sections from two inches in thickness to seventeen inches in thickness.

Unfortunately time did not permit me to analyze and comment on the second part of Mr. Merten's paper very thoroughly, but exception should be taken to the very high normalizing treatment that Mr. Merten advocates. If forging temperatures are controlled, both in the heating operation, and if the forging is prolonged through the critical range, there is no necessity to go to this high normalizing treatment, and a treatment of approximately 1650 to 1675 degrees Fahr. is sufficient.

In order to obtain a uniformly distributed structure, it has been our practice in forgings of high stress, forgings of importance, to also resort to the "loneal" for the spheroidization of the pearlitic constituent, and in the years that we have conducted these investigations, I do not remember one instance where we have not been able to obtain satisfactory results.

The value of Mr. Merten's paper should be appreciated by the steel casting industry and more particularly the users of steel castings, although it is believed that a few of the foundries would naturally take exception to the cored bar. From any angle the standardization of a so-called cored bar in place of a test coupon would unquestionably mean more than one heat treatment to meet a physical or miscroscopic test.

It is with interest to know that Mr. Merten has recently been investigating along lines that were investigated and conclusions drawn in the paper presented at the American Foundrymen's Association, convention at Milwaukee, October 11 to 16, 1924, and compiled by Messrs. Harper and Stein of the Allis-Chalmers Manufacturing Company.

The object of the paper presented at that time was to give the results obtained in investigations of the treatments of cast steel which had extended from 1922 to the time of presentation of the paper.

In May 1922 the Allis-Chalmers Company saw the necessity of heat treatment for the body of the casting instead of the test coupon which had erroneously been the practice prior to 1921. In May 1922 examination of cored test bars was started and continued until a class of treatment was developed which has been the practice since.

In furthering the comments of the paper just presented, more stress should have been laid to the fact that even though a phyical tensile test appears to be acceptable, judgment should not be derived from this alone, and it is very necessary that the microscope be used to determine the effect of the heat treatment. We have found it such that although we get a wonderful test from the casting sometimes that the structure of the casting still has its apparent ingotism, or so-called Widmanstatten structure. Physical tensile tests and microscopic examination are now specified on all important castings.

In commenting on the initial temperature used I do not believe it necessary to go above 1650 to 1675 degrees Fahr. in any case providing enough time at temperature is given to bring about the results desired. It has been our practice of 2 hours per inch of thickness at temperature, but this can be lowered on the critical anneal and maintain the same time at the temperature for the spheroidizing treatment as in the critical treatment. The excessively high temperature as used in Mr. Merten's investigations is not desirable due to the excessive scale that results due to the high temperature with prolonged

exposure at the high temperature. The matter of blocking and sagging of the casting should also be considered when using this excessively high temperature especially on castings of intricate design and heavy weight.

The critical temperature should be about 10 to 15 degrees Fahr. above the center of the transformation range.

In conclusion I wish to compliment Mr. Merten on his excellent paper.

Written Discussion: By A. W. Lorenz, Bucyrus Company, Milwaukee.

Mr. Merten's paper is a welcome contribution to the question of steel casting annealing practice. There is at the present time comparatively little information on the heat treatment of heavy sections. The writer has not been especially concerned with the treatment of sections as heavy as those investigated by Mr. Merten, but we have done a small amount of work in the treatment of sections ranging from four to six inches thick.

For purposes of investigation we cast a block four inches thick, fifteen inches long, and twelve inches high, surmounted by a feeder six inches square along the full length of the block. From the lower four inch section were cut horizontal slices, 1¼-inch thick. Bottom and end sections were discarded. The trimmed slices were then subjected to various single and multiple annealing treatments in which the first heat ranged from 1500 to 2000 degrees Fahr. The steel in this block was especially poor, and results were disappointing. With an ordinary air-cool anneal at 1650 degrees Fahr., followed by a 1200 degrees Fahr. temper, the outside tests off the slice so treated gave an average of only ten per cent elongation and twelve per cent reduction. The center test gave six per cent elongation and eight per cent reduction.

On another slice annealed at 1950 degrees Fahr. for ten hours, followed by a subsequent anneal at 1550 degrees Fahr. and a temper at 1250 degrees Fahr., the average elongation of the outside tests was raised from ten per cent to 17½ per cent, and the reduction of area from 12 per cent to 20½ per cent. The reduction of area on the center bar was raised from 8 per cent to 15.9 per cent, but the bar broke in the punch mark. Notwithstanding the poor nature of this block of steel, the improvement in ductility with high temperature treatment was notable.

Further blocks were cast subsequently, after changing the method of gating, and the same procedure resorted to, one block being 4 inches thick, and the other six inches. Some sixty tensile tests and thirty Charpy tests were cut from these blocks after slicing and subjecting to various treatments. Without entering too much into detail, the results may be summarized as follows:

Ordinary annealing at 1650 degrees Fahr., followed by air cooling yielded approximately 45,000 pounds per square inch yield point, 74,000 pounds per square inch ultimate, 28 per cent elongation, and 44 per cent reduction, on both the center and outside tests, the center tests being fully equal to the outside. Charpy value on the center bar was 24.7 foot pounds compared with 19 average for outside tests.

Multiple annealing, with a first heat of 1800 degrees Fahr. and the second 1500 degrees Fahr., gave the same yield point and ultimate as above, with an average improvement of five to eleven per cent in elongation, four to ten per cent in reduction, and four to fifteen per cent in Charpy value. Tests

heated to 2000 degrees Fahr. for five hours showed no further improvement.

Our conclusions based on the above investigations are that when castings six inches or less in thickness possess a good initial structure, extreme high temperature annealing is unnecessary; but where the initial structure is not known, which is usually the case, or where it is known to be poor, a high temperature treatment recommends itself as an excellent safety factor.

While we have not had ocoasion to investigate sections such as described by Mr. Merten, it is my feeling that difficulty in refining a cast structure increases with thickness of section and that the treatment recommended by him would be highly desirable. For castings under four inches in thickness, I do not believe that extreme high temperature treatments will justify themselves in commercial castings in view of the increased costs, excepting to fill a specific engineering demand. We have here not only the extra annealing costs to consider, but also the poor appearance of the casting and increased wear on cutting tools due to heavy scale produced.

Reference is made to limitation of silicon content. Aluminum is also very detrimental, as every one knows. It may not be so generally understood that the use of aluminum in cast steel is not related to furnace practice nearly so much as to sand conditions. Thus steel made by any of our present commercial processes will produce a sound casting in dry sand without the use of aluminum, whereas the same metal poured into green sand will develop pin holes. Since large castings are made almost exclusively in dry molds, and small castings generally in green sand, the custom of adding aluminum is more prevalent in small castings. It seems therefore that aside from the question of heat treatment, considerable thought might be devoted to the use of so-called ladle additions, as related to molding practice.

Written Discussion: By C. E. Corson, Edgewater Steel Co., Pittsburgh.

The results speak for themselves. While such a drastic treatment had been more or less successful in the treatment of forgings made of nickel ordnance steel, yet we had never considered the use of a 2200 degrees Fahr. temperature as a means of raising the ductility and elastic limit of a mild carbon steel. I have seen these results substantiated by many others and am convinced that the physical properties of a mild steel can be greatly improved by the treatment Mr. Merten outlines. This improvement has been noted in steels which contained sonims, as well as an ordinarily clean steel.

Oral Discussion

Sam Tour: Mr. Chairman, some four or five years ago, working with a chromium vanadium die steel not on the basis of physical tests from the steel but on the basis of response to the final heat treatment ordinarily applied to that type of steel, we found that the preliminary treatments necessary were largely based, upon final forging temperatures and not upon composition of steel. One might say that temperatures such as Mr. Merten recommends are only necessary if the final forging temperature is very considerably too high. In other words, treatment should be based upon final forging temperature, and in the preliminary treatment it is only necessary to go to about 100 degrees above the final forging temperature.

Author's Reply to Written Discussion

W. J. MERTEN: Mr. Chairman and gentlemen: In order to reply to Mr. Bull's discussion, I want to stress this point, that small sections or irregular sections of castings become dangerous only because of shrinkage cavities rather than structural irregularities after these treatments. We have verified this frequently, and consistently obtained structural uniformity and refinement in the smaller sections as well as in the heavy sections. However, defective sections at changing portion, when subjected to high temperature treatment, reveal themselves by producing a crack or in some other way give evidence of this defect.

In regard to the question of silicon control, I want to refer to the figure on the seventh page of the paper. The statement is the result of metallurgical research work with regard to silicon contents in this type of casting. The foundry practice that produced these castings successfully paid particular attention to this factor. Other foundries which followed the general practice referred to by Mr. Bull, failed to meet the requirements.

In regard to Mr. Stein's discussion about his work on core drill tests, I want to call attention to the fact that core drill tests were employed as a means to prove high temperature refinement of castings and structural refinement by high temperature treatment. If it had been expedient, I would probably have cut the casting in two to verify results by bars taken from the middle of the castings by some other machine tool. I was interested entirely in high temperature manifestations. I also am not surprised at the retention of Widmanstatten structure and dendritic segregation in the castings he describes. At the low temperatures employed they cannot be removed. However, they can be removed, at higher temperature. Normalizing at a temperature from ten to fifteen degrees above the upper critical point, seems to me a refinement which is very hard to introduce into a foundry, and is an unnecessary restriction in view of the results of the experiments given in my paper.

In this connection also, I want to say that I have been told by the foundrymen who heat treat castings at high temperatures, whenever they have a casting that is made from a wild heat resulting in a spongy material, that after this heat treatment, it is almost impossible to take a test bar from it.

In reply to Mr. Lorenz's discussion, I would say that the temperatures, which he states may be correct for smaller size castings, they are, in my opinion, somewhat low for best structural refinements on castings of sections such as I have had to deal with.

In answer to Mr. Tour's remarks, I certainly agree with him, I would not heat treat a die block forging used for die-casting (which has been subjected to a thorough low temperature forging operation) at a temperature of 2000 degrees Fahr. for structural refinement. It is not necessary for that class of material. I was dealing with forgings of much larger masses, weighing anywhere from ten to fifteen thousand pounds and of 55 inches or more in diameter and eight to ten inches thick.

THE MELTING OR MOLTEN STAGE OF STEEL MANUFACTURE WITH PARTICULAR REFERENCE TO THE DEOXIDIZING, REFINING AND CONTAMINATION PHASES

By G. A. Dornin

Abstract

The writer brings out in this paper the extremely bad effects of oxides in steel and points to the only known methods for their removal from the molten bath. He discusses the various steel melting processes and shows their possibilities for good steel making as shown by their capacity to make steel free from or relatively free from oxides. No attempt is made to discuss the flaws of steel due to improper solidification nor those due to bad treatment but the statement can be made that unless steel is properly melted it will not solidify properly nor can it be properly treated.

MEN are known by the company they keep. Steel also may be largely known by the company it keeps; namely, the slag under which it is produced and protected from outside influence until cast. There are only three major stages or divisions of steel making, each having its own special effect or effects on the character of the metal. These are:

1. Melting or Molten Stage
2. Ingot or Solidification Stage
3. Working or Treatment Stage.

The first stage covers steel making up to the point where it is poured into molds and solidification begins. It determines the analysis, freedom from extraneous or unwanted matter such as dirt, sonims and oxides and governs the method by which the ingot or casting forms. The second stage covers the going of the molten into the solid and determines the location of the shrinkage volume and the uniformity of the ingot or casting.

The third stage includes the working (rolling or forging) of

A paper presented before the ninth annual convention of the society held in Detroit, September 19 to 23, 1927. The author, G. A. Dornin, a member of the society, is metallurgist and consulting engineer with the Gathmann Engineering Company of Baltimore. Manuscript received July 14, 1927.

the ingots into some useful shape or form and the treatment of these forms either by heat or otherwise to produce certain desired results. The effects of this third stage are largely on the crystal size and the form of the carbon, hence entirely on physical characteristics.

The author will confine himself in this paper to a discussion of the first stage; *melting or molten stage* and will mention the other two only as necessary to make clear the points brought out.

Steel making processes are almost universally known by their method of melting and treating while molten.

The best known processes are: (1) Crucible, (2) Bessemer, (3) Open-Hearth. Many may say that the electric furnace is a fourth process, but I prefer to consider it as a special form of open-hearth, the main difference being that the heat is furnished by the electric arc instead of by the combustion of fuels.

In the crucible process wrought iron or steel scrap of predetermined analysis is melted in a clay or graphite crucible. This protects the molten metal largely from outside influence and gives a chance therefore to produce a pure clean product. The only sources of contamination are the erosion of the crucible, the oxides present in the charge and the air in the pot itself. These latter causes of oxidation, while slight, are, as a rule, sufficient to make it necessary to deoxidize and refine before the melt is ready to cast. The process is limited to melting in small quantities, is expensive and the results are so closely approximated by small electric furnaces that in this country it is largely dying out.

The first process which permitted the making of large tonnages of steel was the Bessemer process. This consists in blowing air through molten pig iron thus oxidizing out of the bath carbon, silicon, and manganese. Toward the end of the blow the bath is deoxidized with manganese or spiegel; carbon, silicon and manganese or any of these are returned to the steel in the desired amounts usually in the ladle when the heat is tapped. The process is worked either acid or basic, the latter getting rid of phosphorus as well as the other elements.

Closely following the Bessemer process came the open-hearth in which pig iron and steel or iron scrap are melted down in a regenerative furnace, the burning out of unwanted elements being accomplished by additions of iron ore (oxide) or of scale or cinder carrying a high percentage of iron oxide. In some cases the oxidiz-

ing effect of the flame is sufficient to do all that is necessary, but in most cases ore is added. The acid open-hearth process does not remove either phosphorus or sulphur while the basic open-hearth process does remove both and if properly run, to very low percentages.

With this brief mention and description of the various major steel-making processes the writer proposes now to show their relative possibilities in the making of clean sound steel, the aim of all good steel making.

It is the writer's firm belief that practically all evils of steel making can be traced to the presence of oxygen in some form in the solidified product, and that the best steel is that which contains the least oxygen. This is a rather sad fact to face because in all of the steel making processes except the crucible process oxygen in some form must be introduced into the bath to burn out the elements not wanted in the final product; so that the problem resolves itself into a means of getting oxygen out of the bath after it has performed its function.

This can only be done by causing the oxygen in the bath to form compounds not soluble in the bath but still fusible at the bath temperature so that by the laws of colloidal chemistry they will collect themselves into particles which are large enough to float up out of the bath into the slag. Having gotten them into the slag, this must be in such condition that it will retain these unwanted products of oxygen, and not return them to the bath. The causing of oxygen, soluble in the bath, to take a non-soluble form is commonly called deoxidation.

Refining means the getting out of the bath by flotation, the products of deoxidation. Contamination means the return to the bath chemically or mechanically of elements which have previously been removed by melting, deoxidation and refining.

These three phases deoxidation, refining and contamination, the causing of the first two to take place and the prevention of the third govern the percentage of oxygen in the final product, and hence the ability to properly carry out these three phases in any steel making process rates the ability of that process to make sound clean steel.

At relatively low melting temperatures, iron, silicon, manganese and phosphorus have a greater affinity for oxygen than has carbon,

while at relatively high melting temperatures carbon has a greater affinity for oxygen than any of these and hence will reduce the oxides of any of them.

The major contaminating factor affecting a bath of steel that has been deoxidized and refined is the iron oxide present in the slag. It is only through this iron oxide that reoxidation can take place, FeO in the slag being oxidized to Fe_2O_3 by the flame which on coming in contact with the bath along the slag bath line breaks up again into FeO, oxidizing iron in so doing. This FeO is soluble in both bath and slag, and if a bath practically free from FeO is left in contact with a slag carrying FeO the bath quickly takes up FeO until the slag and the bath are in equilibrium with reference to FeO. The total amount of contamination therefore that can take place has a direct relation to the total amount of FeO present in the slag to accomplish this undesired result, and the time the slag and bath are left in contact with each other; because all mass action takes time.

The best method of deoxidizing a bath of steel is by the introduction of silicon which reduces FeO in the bath to form SiO_2 This is infusible at the bath temperature, but on formation finds itself in the presence of FeO with which it forms slag globules fusible at bath temperatures which coalesce and grow until they float up into the furnace slag. Silicon therefore performs a double function in the removal of FeO from a bath of steel in that it reduces FeO to form SiO_2 and this SiO_2 fluxes out still more FeO. It probably also fluxes out of the bath MnO and MnS. Manganese on the contrary while it is a deoxidizer has a lesser affinity for oxygen than has silicon and also it has no effect in the removal of FeO by fluxing. Aluminum is the most powerful deoxidizing agent at our command. It probably has a fluxing as well as a reducing effect. Its cost and the difficulty of getting it to function at the slag-bath line, due to its lightness, largely limits its use to a final corrective added when the steel is tapped into the ladle after the major part of deoxidizing and refining has been carried out in the furnace with the cheaper and more easily handled elements.

Carbon functions as a deoxidizer only at high bath temperatures. As its oxide is a gas it is better than any of the other deoxidizers, because the others all leave solid non-metallics, which take time to get rid of by flotation, and are never completely

eliminated. It is, as a rule, made use of, to some extent, in both acid and basic open-hearth processes, and very largely in the basic electric process, where two slags are taken, the first or oxidizing slag being removed, and a second or refining slag free from iron oxide being formed, usually of lime and carbon.

The total amount of contamination that can take place has a direct relation to the total amount of iron oxide present in the slag. It is also governed by the relative freedom of this iron oxide to do its work of contamination. This is greater for basic slags than for acid slags and for this reason acid slags are less oxidizing than basic slags. It is also possible with acid slags to deoxidize both bath and slag; while a basic slag carrying phosphorus and sulphur, if the slag is deoxidized, there is always danger of deoxidizing these two elements, and driving them back into the bath, and this is almost certain to happen if this slag deoxidation is carried too far.

One must therefore rate steel made under an acid slag as cleaner than steel made under a basic slag, unless the basic slag is a second slag free from iron oxides, in which case one would expect to find cleaner steel under a slag which carries no iron oxide, to do the work of contamination. Furthermore, the slag free from iron oxide prevents any transferring of oxygen from flame to bath, and this always goes on to some extent when there is iron oxide in the slag. With this slag blanket free from iron oxide, one can prolong the refining period to the extent desired, and the steel made under this type of slag should be cleaner than steel made under an acid slag. There is also a limiting feature in the deoxidizing of the bath and slag in an acid furnace; as this builds up silicon in the bath which may be above the percentage desired.

The electric furnace is an open-hearth furnace and as its cavity is not sealed oxygen must always be present in its atmosphere. Its temperature control is better than a gas-fired furnace and there is probably less oxygen present in its furnace atmosphere.

The various steel making processes according to their ability to make sound clean steel must therefore be rated as follows:

First: Crucible; because of absence of, and freedom from, iron oxides, all through the process

Second: Open-hearth; because while the process depends on oxidation during melting it permits of deoxidation and refining at the end of melting

Third: Bessemer; because its oxidation is greatest and no opportunity is given to deoxidize and refine, except to a limited extent and that largely in the ladle.

The various types of slag covering the bath and produced during melting must be rated as follows:

First: Slag free from iron oxides such as the second slag on a basic furnace

Second: Acid slags

Third: Basic slags carrying phosphorus and sulphur.

The writer's object in the presentation of this paper is to bring about a discussion of certain vital factors which govern good steel making. It is not offered as an addition to our present knowledge of the art, but is an attempt to analyze the subject to its basic elements, and build up the argument from research that is already established, and also to point the need of further research to clear up points under discussion; with the hope that present day plants can be operated along sounder metallurgical lines, toward a supply of better steel for all.

DISCUSSION

Written Discussion: By John E. Arthur, Union Electric Steel Corporation, Pittsburgh, presented by W. H. White.

It is regretable that the author has considered the manufacture of steel in the electric furnace as a special form of open-hearth instead of a distinctive process. This unusual classification clouds the issue and tends to confusion.

While there is a relation between the metal and the slag to a very marked degree, it is a fallacy to assume that the qualities of the various processed steels should be judged proportionately by the amount of iron oxides their respective slag contains. If this assumption were true, the basic electric furnace slag under only average refining conditions, being so low in iron oxides, its metals would stand out preeminently among the other processed steels. The author discusses the reactions between the slag and metal in the different processes and definitely states, that in the steel made under carefully operated basic electric furnace practice, one would expect to find a clean product. This is true and steels thus made, whose oxides of iron and manganese total less than 2 per cent in the slag, exceeds the quality of crucible steel, whose acid slag contains 8 per cent and over of iron and manganese, and permits of the manufacture of certain products, through its perfect reducing atmosphere, that cannot be approached by any of the other processes.

Although the author confines his treatise to the melting or molten stage,

he has not introduced for discussion a minor step or stage of the operation, that assumes proportions at times as a major factor in the making of clean steel, namely the transfer of metal from the furnace to the mold.

The writer contends that as much clean steel becomes contaminated with oxides of silicon and aluminum after leaving the tap hole of a furnace, as there is contamination of steel prior to tapping through incomplete refining. This type of contamination can occur through the churning of slag into the steel when tapping; scorification of the furnace spout, ladle lining, stopper sleeves and nozzle.

Proper viscosity of the slag and size of the tap hole, permitting complete retention of the slag until the metal is drawn from the furnace, will eliminate contamination from the first source. A short spout lined with a highly refractory material and having the least possible area is seldom the cause of introduction into the steel of extraneous matter.

The ladle should be lined with hard, dense brick, closely jointed, refractory enough not to soften so as to withstand the frictional action of the metal when receding in the ladle while pouring. The stopper sleeves are subjected to the same conditions as the lining and must receive like precautions. The nozzle, in addition to the foregoing actions, receives a greater test, namely to withstand the ferrostatic pressure localized over its small area. This action tends to displacement of its face, if approaching its softening point. The design of the face of the nozzle is as important as its refractory value in eliminating this frequent source of contamination.

The contamination of the metal in its transfer from furnace to mold is usually called sand splits, and is more dangerous to steel in its responsiveness to heat treatment and subsequent service, than possibly a few inclusions directly traceable to incomplete furnace reactions; not that we countenance the manufacture of such steels but rather to point to the importance of having perfect ladle conditions as well as good furnace practice to produce good clean steel.

Written Discussion: By H. M. German, metallurgist, Universal Steel Co., Bridgeville, Pa.

The classification of the electric furnace as a special form of open-hearth is a great injustice, as the quality of steel produced by sound electric furnace practice is superior to that made in the open-hearth furnace.

The difference in quality may be attributed to the following operating advantages of the electric furnace over the open-hearth furnace.

1—Quicker and better control of temperature

2—Higher temperatures are available which means that slags higher in lime and carbide slags can be used which give a better removal of sulphur, oxides and gases.

3—The steel can be finished in the furnace, as alloy additions can be added directly to the bath with little loss and the heat can be held at a given temperature until all alloys are in solution, and their non-metallic reaction products will have time to free themselves from the metal and enter the slag.

4—The melting practice is more flexible since it can be carried out with slight oxidation, with partial oxidation or with complete oxidation.

Electric furnace steels, made by sound practice, are denser, contain less inclusions of slag, emulsified oxides, segregations and gas than open-hearth steels and are consequently stronger and tougher.

While it is true that the hearth of the electric furnace is open, there is not a steady current of gas passing over the charge, as in the open-hearth furnace, and in view of this difference in operation, and in the quality of steel produced, it is unjust to create the impression that the electric furnace is a form of open-hearth. The electric furnace and its manipulation for making steel is recognized as an individual practice and should so remain.

The writer agrees with Mr. Dornin that a large portion of the evils of steel are due to the presence of oxides. Accepting this hypothesis, the problem of the metallurgist in making quality electric steel is to so control the furnace charge and operation that the smallest amount of oxides will enter the bath and to eliminate these oxides as completely as possible. In order to simplify the discussion, the writer will confine a few brief remarks to the formation and removal of oxides from a slag off heat of basic electric steel.

Oxides enter the bath from three sources. First, with the charge, second, from oxidation during the melting stage, and, third, from the addition of ore during the oxidizing stage.

The saturation point of FeO in iron at its melting point is approximately one per cent. This amount is decreased with the presence of deoxidizers such as, silicon, manganese, and vanadium. Therefore if more than the saturation amount is present in the bath, it will either be held suspended or emulsified in the metal in a mechanical condition or will float on top of the metal owing to its lower specific gravity.

By selecting clean melting scrap that is not rusted the amount of oxides entering with the charge can be controlled. In making quality steel, ore or scale should not be added until the bath is thoroughly melted. Iron oxide if scattered throughout the bath during the melting or pasty condition is apparently fixed in the bath mechanically and possibly by a chemical action so that it is difficult to remove in the later stages.

The amount of oxides produced during the melting period depends upon the furnace atmosphere, since the charge is not protected by a blanket of slag at this stage, and can be kept at a minimum by keeping the furnace openings tightly closed.

In the oxidizing stage, care should be taken to add only sufficient ore to furnish the required amount of oxygen for the elimination of the desired amount of manganese, silicon, and carbon, and that all action in the bath has ceased before slagging off.

The elimination of oxides from the bath is accomplished by addition of deoxidizers, such as ferrosilicon, ferromanganese, aluminum, ferrovanadium, etc., by a strongly reducing carbide slag, and by raising the temperature of the bath. Deoxidizers such as mentioned above have a greater chemical affinity for oxygen than FeO and will reduce the iron oxide to metallic iron and from the oxides of silicon, manganese, aluminum and vanadium. These oxides rising and coming in contact with a strongly reducing carbide slag are rendered harmless either by combining with the slag or by being reduced and enter the bath.

Increasing the temperature of the bath after the addition of decarburizers will hasten their reaction and the removal of their resultant oxides from the metal by flotation, but sufficient time must be allowed for this action to become completed. A difference in time allowed during this period is often a decided factor in the production of quality steel.

Mr. Dornin spoke of rating crucible steel above electric furnace steel. I think we will have to qualify that assertion by a description of the kind and condition of the materials which are used in the crucible charge. For example, I have seen a number of crucible charges made up in which the washed metal and other metals entering into the crucible charge were heavily covered with rust. Now, this condition certainly is going to put a lot of oxides into that batch of crucible steel. I think that before you can accept crucible steel as being rated above electric steel, we must know more about the general make-up of the charge instead of taking the assertion that crucible steel is better than electric steel without questioning it.

In the same way with electric furnace steel we must also realize that to a great extent the result depends on the method of making the steel and also the charge which is used. When electric furnace steel was first made, electric furnace practice was nowhere near what it is today. In fact, a lot of people used an electric furnace as a cupola and sold the product as electric furnace steel. Also, a lot of people use electric furnaces at the present time as an open-hearth, to duplicate open-hearth practice. That is not good electric furnace practice. If the electric furnace practice is carried out under sound principles, as recognized by leading manufacturers today, we have fully the equal of any crucible steel ever made.

Written Discussion: By C. H. Herty, Jr., U. S. Bureau of Mines, Pittsburgh.

This contribution to the picture of steel manufacture is most valuable. The author has brought out two important facts: first, the influence of iron oxide in the slag on the contamination of the metal, and second, the need for research on the subject of deoxidation. The three common deoxidizers, silicon, manganese, and aluminum are fairly well understood with reference to their deoxidizing power. Quantitative information is, however, lacking and there is little knowledge of the usefulness of combinations of the three. Silicomanganese has been used to some extent in recent years but no one knows what ratio of manganese to silicon in this alloy is the best as far as deoxidation and removal of the products of deoxidation are concerned. There is every reason to believe that other combinations of silicon and manganese, silicon and aluminum, manganese and aluminum and ternary combinations will prove to be far better in giving maximum cleanliness to steel.

This discussion will be divided into two parts. First, a few comments on certain statements in the text; second, a discussion of slag oxidation with reference to contamination of the metal.

In the paragraph on deoxidation, the fourth page, the author states that "SiO_2........probably fluxes out MnO and MnS". The fluxing out of MnO is unquestionably a valuable function of deoxidation with silicon but fluxing out of MnS is rather improbable. Williams (Blast Furnace and Steel Plant,

1923, page 51) shows the effect of silica in mixer slags on the removal of sulphur by manganese in the mixer. When the ratio of SiO_2 to MnO was 0.80, 50 per cent removal of sulphur was accomplished. When the ratio was 1.94 only 13 per cent sulphur was removed. In deoxidizing with silica the ratio of SiO_2 to MnO in the fluxed particle is probably about 20 and one would therefore expect very little sulphur removal.

In the same paragraph it is stated that "Manganese (oxide)......has no effect on FeO by fluxing" and "aluminum....probably has a fluxing as well as a reducing effect". These two statements should be questioned. In finishing deoxidation with aluminum the Al_2O_3 is usually found as very small, irregularly-shaped, particles, which would indicate that no fluxing takes place. With regard to the statement that "steel made under an acid slag......is cleaner than steel made under a basic slag", Pickard (*Journal*, Iron and Steel Institute, Carnegie Scholarship Memoirs, 1912, page 52) compared a number of steels made in acid and basic open-hearths. He found that the average content of oxygen, existing as FeO, of the acid steel was 0.0096 per cent and the basic steel 0.0189 per cent. Unfortunately, no details were given on the manufacture of the steels tested and his results can not therefore be considered as a final comparison of acid and basic steel.

In discussing the effect of FeO in the slag on the oxygen content of steel in the open-hearth, it is necessary first to go back to three general principles: First, that *reaction rate at* 2910 degrees Fahr. (1600 degrees Cent.) is tremendously rapid; second, that equilibrium in a single phase (in this case the metallic bath) is reached quickly; third, that the diffusion of a substance through a single phase or from one phase to another is controlled for given physical conditions, by concentration differences between any two points in the single phase or at the interface of the two phases.

Before iron oxide can react with any metalloid in the bath, diffusion of iron oxide from slag to metal must take place. Diffusion processes are, in general, slow when compared to true reaction rate, and this would be particularly true in the open-hearth furnace where the reaction rate is rapid on account of the high temperatures used, and because the iron oxide must diffuse from the slag, which is relatively viscous, into the metal. It is absolutely safe to state that elimination of metalloids in the open-hearth, and therefore the formation of non-metallic matter or gas, is controlled by the diffusion of iron oxide from slag to metal.

Once the iron oxide has entered the metallic bath, reaction with the metalloids is rapid and equilibrium is established almost instantaneously between dissolved FeO, metalloid and the product of their reaction. In the case of manganese, phosphorus and silicon, the reaction product is in equilibrium with the slag and elimination ceases when the concentration of this product is high enough to provide that the reverse reaction just balances the reaction of elimination. In the case of carbon, however, the product of the reaction is a gas (CO) and is continuously removed from the liquid phase, entering the gas. This allows carbon elimination to proceed after the other metalloids have reached equilibrium. As long as carbon is being eliminated the total pressure of CO at the slag-metal surface is 1 atmosphere plus the pressure

exerted by the slag and since this will be fairly constant, the pressure of CO in the reaction

$$C + FeO \rightarrow CO + Fe$$

may be considered constant at one atmosphere. The solubility of CO in steel changes with changing temperature and to find the true relationship between carbon and FeO it would be necessary to know the solubility of CO in iron over the temperature range encountered in steel manufacture. However, the solubility may be considered constant at a given temperature and may be incorporated in the equilibrium constant for the reaction, which is

$$K = \frac{(CO)}{(C)\ (FeO)}$$

Assuming that CO is constant for a given temperature, the relation becomes

$$K = \frac{1}{(C)\ (FeO)}$$

This means that in the metal phase the dissolved iron oxide will be inversely proportional to the carbon content of the metal, the numerical relationship depending on the temperature. The numerical value of the constant K will vary with the temperature, increasing with increasing temperature, which means that less iron oxide is in equilibrium with a given carbon as the temperature increases.

The diffusion concept as applied to FeO in the open-hearth may be expressed mathematically as follows:

$$\frac{dW}{d\theta} = k\ A\ (\Delta C) = kA\ (CE - CA)$$

when $\frac{dW}{d\theta}$ = the amount of iron oxide diffusing from slag to metal per unit of time,

k = the diffusion coefficient,

A = the slag-metal area,

CE = the concentration of FeO in the metal which would be in equilibrium with the iron oxide in the slag.

CA = the actual concentration of iron oxide in the metal, determined by the carbon content of the metal and temperature.

This equation simply states that the amount of iron oxide dissolving in the metal per unit of time is proportional to the area for diffusion and to the difference between the equilibrium concentration and the actual concentration, this difference in concentration being called the "driving force".

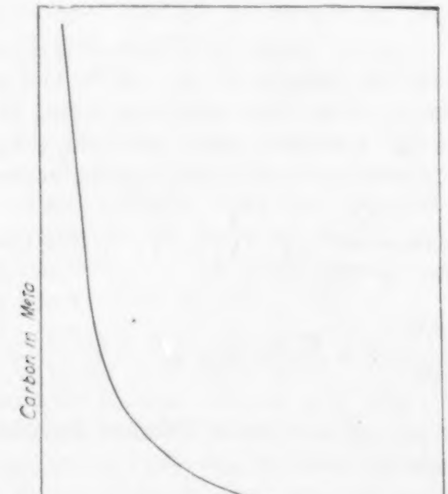
Applying these considerations to the paper in question, the statement on the fourth page that "if a bath practically free from FeO is left in contact with a slag carrying FeO the bath quickly takes up FeO until the slag and the bath are in equilibrium with reference to FeO", is in error in that no ac-

count is taken of elimination of FeO by carbon, or any other metalloid. If the statement were modified as follows it would be correct: ***If a bath practically free from FeO is left in contact with a slag carrying FeO, the bath quickly takes up FeO in an attempt to bring about equilibrium between slag and bath with reference to FeO.***

In order to illustrate the relative contaminating effect of two slags on two baths of steels treated identically, it is necessary to know something about the relation between carbon and iron oxide in the bath, and something about the solubility of iron oxide in iron. Fig. 1 shows the type of curve by which carbon and iron oxide are related in the equation

$$K = \frac{1}{(C)\ (FeO)}$$

At any given temperature a definite concentration of iron oxide will be in equilibrium with a definite concentration of carbon. Now let us assume that the solubility of iron oxide in iron at 2910 degrees Fahr. (1600 degrees



Cent.) is equivalent to 0.30 per cent oxygen (1.35 per cent FeO) and that the iron oxide content of the metal is directly proportional to the iron oxide content of the slag, i.e., a slag containing 25 per cent iron oxide would give 0.30 x 0.25 = 0.075 per cent oxygen in the steel at equilibrium and a slag containing 20 per cent iron oxide would contain 0.30 x 0.20 = 0.06 per cent oxygen.

Our two illustrative heats will have finishing slags containing 25 per cent and 20 per cent iron oxide respectively, and both will be tapped at a carbon content in equilibrium with 0.06 per cent oxygen. This means that heat No. 1, with 25 per cent iron oxide in the slag will be eliminating carbon when tapped and that heat No. 2 will have ceased, or practically ceased to eliminate carbon.

If we are making "rimmed" steel we add ferromanganese, and suppose that enough is added to deoxidize just half-way, the oxygen content of the

steel dropping to 0.03 per cent. As soon as the oxygen content of the steel reaches 0.03 in heat No. 1, iron oxide diffuses down proportionately to the "driving force" which is (0.075 — 0.030) = 0.045 per cent oxygen. In heat No. 2 the "driving force" is (0.060 — 0.030) = 0.030 per cent oxygen and in heat No. 1 iron oxide will diffuse into the metal 50 *per cent faster* than in heat No. 2.

If the two heats were *completely* deoxidized the driving forces would be 0.075 and 0.060 per cent oxygen respectively and in heat No. 1 the oxygen would diffuse 25 per cent faster than in heat No. 2. This illustrates the importance of keeping the slag as low as possible in iron oxide. The writer has known of cases where the iron oxide in the finishing slags has run so high that very heavy losses of silicon and manganese on killed heats, and of manganese and carbon on rimmed heats, occurred. Elimination of these metalloids in the ladle results in the formation of non-metallic inclusions, poor rimming steel, improperly killed steel, and in many cases of parts of heats far below specifications in silicon, manganese and carbon.

Written Discussion: By W. H. White, Duquesne Steel Foundry Co., Coraopolis, Pa.

The paper by Mr. Dornin is, and should be, appreciated by steel makers, because it deals with the principal cause of most steel failures, "Oxides of some form always existing in large or small amounts in every heat made."

Possibly due to his connection with an ingot mold concern has made him reluctant to mention, next to proper slag making, the most important practice in the production of high grade forging ingots which we believe to be "Ingot Mold Design."

When a heat has been made as free as possible from these oxides, the quicker it solidifies the greater the distribution of these oxides through the body of steel, thereby preventing the collecting in any particular location through the center of the ingot, this is done by cold pouring, and heavy mold chill.

The nickel and nickel-chromium steels seem to be more susceptible to this defect known as "flake"; in other words an oxide spot. The only way to defeat it in large and small guns and shells, pipe molds and other forgings where transverse bars are required, is to study the three (3) major practices in steel making, namely, "conditioned slags", "correct pouring temperature", and "large ingot mold chill". Many tons of so-called good steel through the information of longitudinal bars would have a different reputation if transverse bars were in order.

Some metallurgists believe that forging, rolling or treatment can cause this little white spot that shows over the area of the bar, but these operations have nothing to do with their presence. I may be making it hard for some melters when this statement is made, but it remains for them to learn more of their art. I have in mind a year or more of torture in the manufacture of armor plate and guns, and to a metallurgist I owe the first thought as to how the melter can make steel free from this trouble.

Mr. Dornin is in contact with many steel makers and he can do lots of good with his slag, mold, and temperature knowledge in relation with these

so-called "oxides", "sonims" or "non-metallic areas" that break the continuity of grain growth as the steel begins its solidification. This broken grain growth never welds through forging or treatment, and is later the cause of test bar failure.

Oral Discussion

A. B. KINZEL: The problem of properties to be obtained with steel melted in the various processes is one that comes up regularly for discussion and always evokes interest. It seems to be generally granted that if steel is made by the very best practice by any one of these processes, that the properties obtained are pretty nearly equal. The problem then reduces itself to the probability of getting these values in actual practice, or, stated another way, the probable values which will result from steels made in practice. The only way to find that out is to run a probability curve on the various types of steel. The peak of that curve, that is, the probable values obtained, will be increased or decreased by the causal effects, which is another way of saying, by the care in the practice which is used, and as this is generally improved, year by year, the probable properties obtained are increased. That is another way of saying that when the electric furnace was first put into use and practice was poor, the values obtained on the steel did not compare with crucible steel whereas now the probable values obtained are very close to the latter, better or just equal to it, depending upon the specific data which is taken. The way to attack this problem is from the probability standpoint and not from any individual heat or any small number of heats which have been made.

MEMBER: I noticed according to the schedule there was ten minutes still due to be allotted to Mr. Dornin's paper. There were some exceptions taken to his statement on the electric furnace as compared with the open-hearth. We have a chairman here who has had a great deal of experience with the open-hearth and the electric furnace as well. I would like to hear his experience and then hear what Mr. Dornin has to say about that.

CHAIRMAN RADCLYFFE FURNESS: As far as Mr. Dornin's statement is concerned, I agree with him to a great extent. It makes no difference how you introduce your heat. The electric furnace has a hearth the same as the open-hearth. The only difference is that you make your heat by resistance through your slag. This is a decided difference, however, because you have your greatest heat where you want it, where your greatest reactions take place. In that respect the electric furnace has an advantage over the open-hearth and, in my opinion, that is the sole advantage that it has over the open-hearth, that you can introduce the heat at the spot where you need it and make it from the inside, not from outside. Therefore you can get a great deal higher temperatures in the electric furnace and accomplish a great deal more with those higher temperatures. You are not restrained so much as to what you can do by the resistance of your refractories.

G. A. DORNIN: This paper was written primarily to emphasize the importance of low iron oxides in slags. In my own experience I have seen a basic heat, an apparently well-made basic heat, tapped into the ladle at 0.35 per cent silicon and by the time that heat was through pouring, it was 0.08 per cent silicon. I have seen it lose 27 points of silicon and turn from a fairly

well deoxidized steel to a gassy, growing steel, and to keep it quiet, to keep it in the molds, we had to add aluminum in the molds. Basic open-hearth steels today are being made with iron oxides in the slag as low as 7. That is the lowest I have heard of. In some well-managed plants they are running reliably around 10 and 11.

I have not the slightest axe to grind with electric furnace steel. They are already doing in the electric furnace, with the lime-carbon slag, what the next step in the basic open-hearth will probably be, at least, in my opinion. If we can not use an iron oxide-free slag in the furnace, we can at least use a slag that is free from iron oxide, or has very little iron oxide in the ladle, and I am hoping that the discussion of this paper will attract the attention not only of metallurgists, but of the men in the plants, melters, first helpers, the men who actually do the work, whose skill and whose understanding has much to do with tonnage quality, that is, the total quality, the results of which you people who have steel to use are dependent on. It was to bring that point out and to try to bring it out in language simple enough for them to understand that this paper was written.

DR. C. H. HERTY JR.: Mr. Chairman, could I make just one point? When Mr. Dornin spoke of a steel being made with a 7 per cent iron oxide slag, I think he has to specify what kind of steel is being made when he talks about the iron oxides in the slag. With a 7 per cent iron oxide slag, I am certain that you could never make a 0.10 per cent carbon steel, you would have to go up higher. On the other hand, for a forging grade steel a 7 per cent iron oxide slag is very good practice.

G. A. DORNIN: It was a forging grade steel.

DR. C. H. HERTY JR.: If you see a 20 per cent iron oxide slag on a soft steel you do not want to think that the slag has 13 per cent too much iron oxide.

E. R. YOUNG: With regard to the control of iron oxide in the slag, I would like to ask the opinion of some of these gentlemen as to the importance of the influence of furnace atmosphere.

H. P. EVANS: The electric furnace was first used in the manufacture of carbides. A reducing atmosphere was maintained by the use of coke. During the first few years of electric steel practice the charge was melted down in an oxidizing atmosphere by the use of an oxidizing slag, and then finished under a deoxidizing slag. Due to the loss in easily oxidizable valuable alloy constituents advantage was then taken of the neutral atmosphere by melting down and finishing under a single slag. At first undue precautions were taken, such at luting the doors etc., in order to prevent the supposed oxidation. It was soon found, however, that due to the fact that the pressure of the gases is outward and not inward that these precautions were not necessary. Ordinary operations prevent undue oxidation. Finally, what is probably most important, the carbide slag obtained is unique to electric furnace operations, and drives any metallic products from the slag back into the bath and completely deoxidizes the bath.

A. N. CONARROE: Mr. Chairman, I think the last speaker was talking in answer to Mr. Young's question in regard to the electric furnace. I think that could be carried a little further and the question be asked as to the effect

of the atmosphere in the open-hearth. Unquestionably the atmosphere in the open-hearth can be maintained oxidizing or neutral or almost reducing. Now, I think the question that was asked by Mr. Young might be carried further to the open-hearth as well as the electric furnace; namely, the effect of the atmosphere upon the steel.

A. L. FEILD: Mr. Chairman, it seems to me that we should not talk about the furnace atmosphere without taking the slag into consideration, because it is the slag only which is in contact with the furnace atmosphere. A slag containing carbon, which can be burned off to produce CO, may itself produce a neutral or reducing atmosphere, but in the absence of the carbon in the slag, it will be oxidizing in every case.

W. S. BUTTLES: The formation of silicon carbide under the arc is a very fine deoxidizer, and that is one feature which the direct arc electric furnace has that no other type of melting furnace would have. The silicon will form silicon dioxide and go into the slag and the carbon will form carbon monoxide or carbon dioxide. This kind of deoxidizer is something you could not possibly get in an open-hearth or in a crucible.

CHAIRMAN RADCLYFFE FURNESS: If you will allow the Chair to reply to you, sir, there is no question that the electric furnace has a decided advantage in the fact that the greatest heat is where it will do the most good in the slag. Therefore, you can make those various compounds that you mentioned, which you cannot make in either the acid or basic open-hearth, at least, they have not been made to my knowledge today.

VICE CHAIRMAN R. H. PATCH: Mr. Furness, you do not think that there is a point in relation to silicon carbide in the case of the electric furnace, in that it does not play as efficient a part as it would appear to, on account of the layer effect existing in the electric furnace, which you do not have in the open-hearth, and where, as a consequence, you do not have deoxidizing conditions in the basic electric so much improved over the acid open-hearth, as would appear to exist from the presence of the silicon carbide?

CHAIRMAN RADCLYFFE FURNESS: In reply to your question, I can say that might be. One of the weaknesses of the electric furnace is the lack of motion in the bath. There is always the danger, in my experience, of having the top of the bath in perfect condition without knowing what the bottom is. One can stir it up, but that is very inefficient. It is rather like stirring a cup of coffee with a tooth-pick. That is the great danger that I see in the electric furnace, the layer effect. But with care and time, that can generally be handled.

J. R. ADAMS: Mr. Chairman, I would like to bring out one point that seems to have been missed here with respect to the acid open-hearth furnace, that if the heat is very thoroughly settled and the slag is in perfect condition, it is perfectly possible to reduce 25 or 30 points of silicon and bring it into the bath. It is also possible to reduce chromium to a limited extent from an acid open-hearth slag if the chromium content of the bath itself is, we will say around 0.90. I have seen it happen. When the heat is hot and the slag is in very good condition, I have also seen small quantities of manganese reduced from the slag.

Now, of course, there is no question that carbides can be formed, it is not a possibility; but, nevertheless, you can reduce silicon and, under certain conditions, where the conditions are just right, you can reduce chromium, manganese and tungsten from the slag.

H. B. SCHULZ: Speaking of the layer effect that you mentioned in the electric furnace, we have partly overcome that by tapping about three-quarters of the heat into the ladle and then pouring it back into the furnace and giving it sufficient time to thoroughly deoxidize again.

GEORGE BATTY: I wish to endorse, Mr. Chairman, your expressed opinion that basic electric steel can be produced of high quality and of perfect soundness without the usual addition of aluminum. As a general rule, however, small amounts of aluminum are added to the steel, basic electrically produced, for steel castings to insure freedom from such defects as are likely to arise from oxidation incidental to casting into sand molds.

Unfortunately, I did not hear the paper presented nor have I seen a copy of the paper, but in the discussion to which I have listened no mention has been made,—in reference to basic electric steels,—of over-reduction. It may be common knowledge to many present that the basic electric process presents opportunity for much more complete reduction than is practicable in the acid open-hearth process, the acid electric process or the basic open-hearth process, and the effects of this over-reduction become most apparent when the steel is to be used in the production of light steel castings.

Dr. Andrew McCance has stated that certain steels, notably high chromium steels and high silicon steels, present a peculiar phenomenon, in that they give up a considerable proportion of their surface heat as light. In the making of ingots, bottom-poured, from such steels, McCance experienced trouble through short run ingots in the groups. This was due to the freezing of the steel on the surface in the molds during casting, generating a back pressure greater than the ferrostatic pressure of the superimposed metal in the trumpet.

I am of the opinion that a similar condition arises when plain carbon steels, say of 0.18 to 0.25 per cent carbon, are produced in the basic electric furnace under extravagantly reducing conditions, and I associate the sluggishness of these steels to the absence of an unknown proportion of dissolved oxide or sub-oxide of iron in the steel. It is probable that both the high chromium steels and the high silicon steels mentioned by McCance are, because of their composition, over-reduced and free from this presumed dissolved oxide of iron.

These over-reduced mild steels from the basic electric furnace are very sluggish in the molds, and such a steel is therefore somewhat of a menace in the production of light steel castings, as through giving up its surface heat as light, the steel is unable completely to run and fill the mold.

The reason I have expressed the opinion that dissolved oxide of iron is an essential to fluidity in low carbon steels is that I have used oxide of iron in various forms to bring about what I considered correct conditions in the steel for the production of light steel castings. One particular instance concerned a heat of about five thousand pounds in weight. The steel was very sluggish, although it was extremely hot. The fluidity of the steel was tested by means of a spoon sample, such sample being taken from the furnace in a spoon well

coated with slag, but the surface of the steel free from slag. The moment the spoon left the furnace sill (door sill), a stop watch was pressed and the number of seconds counted until a solidified film formed over the surface of the metal in the spoon. In the present instance the spoon time test gave only a fluidity reading of 22 seconds, although the metal was obviously very hot. Therefore, to test out the theory that oxide of iron was essential to fluidity, I had 112 pounds of rusty plate scrap charged into the furnace.

This was immediately rabbled in and, because of the great heat of the bath, was rapidly assimilated. A spoon sample was taken immediately after the rabble was withdrawn, that is, within two minutes after the scrap was put into the furnace, and gave a time-temperature reading of 51 seconds, the steel rising very slightly in the spoon.

With no addition of deoxidizer, a further sample was taken, which gave a spoon time test of 48 seconds and was perfectly sound.

Now, let it be understood that there must have been a considerable reduction in temperature when over 100 pounds of cold scrap was added to 5000 pounds of liquid bath, yet, despite the drop in temperature, the fluidity increased very considerably.

On other occasions where a heat of steel has been obviously over-reduced, other methods have been used of introducing oxide of iron to the bath, either millscale or finely powdered ore being added to the slag. In any case, the addition of oxide of iron to the steel corrected the condition and produced the requisite degree of fluidity for the production of light steel castings.

It must be admitted that if the maximum of sulphur elimination is to be achieved, strongly reducing conditions must be obtained in the basic electric furnace, but where the sulphur content of the raw materials is such that little or no desulphurization is essential, it is possible to produce basic electric steel of a very high degree of fluidity, making practicable the production of light steel castings from this metal.

Slag and steel are constantly striving toward equilibrium, therefore, any addition of oxide of iron to the slag will affect the bath, the reverse also being the case.

A slag which falls to a white powder on cooling, or to a grey powder, indicates extravagant reducing conditions, and it is reasonably safe to assume that a steel produced under such a slag would be of a sluggish nature and therefore unsuitable for the production of light steel castings.

My instructions to the steelmakers were that they were not to take metal from the furnace in the over-reduced condition, as such steel almost inevitably resulted in a number of short-run castings being produced. By "steelmakers," it should be understood that I refer to the chemist in charge of the furnaces and not to any outside supplier.

The term "dissolved oxide" may be a misnomer, but it is used to differentiate between an oxide which, to my mind, is responsible for the increased fluidity of steel and that oxide which would cause, by reaction with the carbon of the steel, the formation of blow holes. I prefer to call a steel which I assume to contain some unkown proportion of this dissolved oxide a normal steel, and I am able to tell you that such a steel is of finer crystal grain size

than is a steel of similar chemical composition in respect to carbon, silicon, manganese, sulphur and phosphorus, but over-reduced. This normal steel produced from the basic electric furnace machines more easily, although it is of a somewhat higher Brinell hardness, than the over-reduced steel of apparently similar chemical composition, and it also takes a finer finish, both these being points of economy in the production of machined components.

In attempting to secure the requisite degree of fluidity, when basic electric steel has assumed the over-reduced condition, there is an acute danger of getting excessive temperature and even fluxing the roof refractories and so unbalancing the steel as to silicon content.

F. A. Melmoth has pointed out that mild steels, particularly for castings in green sand molds, should not contain more than 0.35 per cent silicon. Otherwise, there appears to be a danger of spongy castings, because such a steel seems to be unable to retain in solid solution the absorbed gases.

Here, then, is another reason why the over-reduced condition should be avoided, and to those of you who are responsible for the production of steel castings by the basic electric process, I cannot too strongly recommend a careful supervision of the final stages of the melting operation, in order that you may avoid bringing about this over-reduced condition which I have indicated. It is, however, easy, once the condition is recognized, to bring the steel back to normality by the addition of iron oxide in some form or other. If the bath is obviously too hot, rusty scrap may be used and the excess heat utilized. If the bath is of correct temperature but over-reduced, the condition may be corrected by the use of mill scale or iron ore.

W. J. Merten: Mr. Chairman, the last speaker injected into this discussion the user's viewpoint of steel making, and I think it is the right one to inject at this time. However to tell the steel maker to make steel or a casting under a definite slag and under specific conditions would be folly. We have a very much better tool to obtain quality castings and forgings. I think everybody will agree with me, that if I specify physical properties, and insist upon getting them, that the steel maker will be compelled and try his utmost to obtain material that will meet service conditions and service requirements, but to specify slag condition or steel made under a certain set of conditions cannot but get the user into trouble.

Author's Reply to Written Discussions

I am most grateful to all who have joined in the discussion of this paper and wish to thank them for their most valuable contributions to a subject that I know is vital to good steelmaking and that still, in a big way, is imperfectly understood, and the importance of which is very generally underestimated.

If this is not the case, why do the makers of basic open-hearth steel, and 85 to 90 per cent of all steel made in this country is basic open-hearth, try to carry out both the oxidizing and refining phases of steel melting under the same conditions, under conditions that are suitable for oxidizing alone?

The condition that is suitable for oxidizing is a slag carrying a high percentage of iron oxides. This is not the only condition, but this and proper

viscosity are the major requirements. On the other hand, the condition suitable for refining calls for a slag free from iron oxides or at least relatively free.

These two requirements cannot be met with a single slag. Where an attempt is made to harmonize them it merely results in a slowing up of the oxidizing period, and at best a most imperfect refining period with all its consequent penalties in rejections and losses.

Of all the elements (oxides) that go to make up a slag only FeO can be oxidized and hence if the slag of the refining period does not contain FeO it makes no difference whether the furnace atmosphere is oxidizing or reducing, the flame has no chemical effect on the bath except to furnish heat, which is as it should be.

The only big body of men who fully appreciate the foregoing are the operators of electric furnaces. They alone are producing steel which in the refining period of its melting is under a slag which carries no iron oxide, or at least very little. It is this phase of their operation which gives their steel its unquestioned quality and, in my opinion, not the use of the electric arc as a source of heat. This undoubtedly has certain advantages over a gas flame. It also has disadvantages, and both sides of this are well brought out in the discussion.

It is the operators of basic open-hearths who can derive most good from a thorough understanding of the principles brought out and discussed here. As they today do and because of the analysis of our ore and fuel reserves must also in the future produce the big tonnage of our steel, all users of steel must hope that they will be able through better understanding to more closely adhere to the basic principles of good melting.

MACHINABILITY OF METALS

By Orlan W. Boston

Abstract

This paper gives an outline of the various methods which are being used to designate the machinability of metals, and gives under the heading of each method an outline of the work done by various authors as published in a few outstanding papers on the subject. Machinability may refer to the relative machining qualities of several metals under the same conditions or to those of a given metal under varying conditions.

Several methods discussed which have been used to indicate machinability are as follows:

1. *The measurement of the force on a tool to cut a metal under standardized conditions.*
2. *The measurement of the power or energy required to remove a given chip under standarized conditions.*
3. *The ability of a standardized tool to cut various metals, in terms of tool life or cutting speed.*
4. *A measurement of the finish left on the cut surface.*
5. *The penetration of a standardized drill when cutting at constant speed and under given load.*
6. *The torque developed by a drill while drilling various metals under standardized conditions.*
7. *A cutting speed for a certain tool life under standardized conditions expressed in terms of physical properties of the material being cut.*
8. *The hardness numbers of the materials as indicated by a hardness testing machine.*
9. *The measurement of heat generated and the hardness induced by the cutting process.*

THE "machinability" of metals is a term which during the last few years has been given considerable prominence. Like the "hardness" of metals, it is not clearly defined, but may be expressed in several different ways, each quite independent of the other, to designate the resistance of the structure of the metal to the action

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of a cutting tool. Merely to state that the metal is machinable or non-machinable is no longer sufficient, as what may be considered machinable by one process or interpretation, may not be by another.

No completely adequate explanation of just what happens when metal is cut is available. Each chip seems to be removed by various proportions of tear, shear, and flow. Heat is generated by these actions as well as by the subsequent bending of the chip and the rubbing action on the tool. The measurement of the intensity of heat developed has been made by the tool-work thermocouples, as referred to below, but the amount of heat generated by each action independently is as yet undetermined. The lack of such information retards the development of a comprehensive philosophy of metal cutting.

The object of this paper is to outline the various methods which are being used to designate the machinability of metals and to present substantiating data.

Most of the methods which have been used or proposed by various experiments as means of indicating the machinability of metals, deal with the force on the tool or the power absorbed, the life of the tool, or the finish left by the tool. In the first, where the force or power is measured, the material being tested is the only variable, as even an inferior tool will retain its geometric shape and cutting edge throughout a large number of comparative tests. In the second, where the tool life is concerned, the variables of the tool material and treatment are to be reckoned with. This method, however, is more practical commercially, as it is a duplication of actual shop work and also because of the lack of interest of the manufacturer in the first method involving economy of power. The third method, which deals with the finished surface left by the tool, naturally confines itself to those cutting operations which are final and appears to be a function of the tool form and cutting speed.

Several methods which have been used to determine the relative machinability of metals are as follows:

1. The measurement of the force in the direction of the cut on a tool of given geometric form required to remove a chip of definite cross sectional area and shape at a given speed.

2. The measurement of the power required for a standardized tool to remove a specific chip of various materials.

3. The ability of a standardized tool to cut various materials. This may be measured, (a) in terms of the life of the tool for a

given cutting speed, or (b) in terms of the cutting speed for a definite tool life.

4. A measurement of the finish left on the cut surface for various metals under standardized conditions.

5. The penetration of a standardized drill rotating at definite speed and under uniform load when cutting various metals.

6. The torque developed by a drill while drilling various metals under standardized conditions.

7. A cutting speed for certain tool life expressed in terms of tensile strength, reduction of area, or percentage of elongation of the various materials.

8. The hardness numbers of the materials as indicated by a hardness testing machine.

9. The measurement of heat generated and hardness induced by the cutting process.

In the above methods where various metals are being compared, the conditions should be so standardized that the material being tested is the only variable. In some instances, such as measuring the cutting temperatures, forces involved, etc., for a given material as a function of the speed or size of chip, elements other than the material may be varied.

Investigations in the machinability of metals have been made under so many different conditions, by so many individuals, and over such a long period of time, that it is with considerable circumspection the author attempts any complete summary and comparison of results. References to a few outstanding papers which deal directly with the methods of measuring machinability, as outlined above, are made. Much could be gained by a thorough digest and summary of existing data and such a summary would indicate that additional data are needed on the subject to confirm, explain, or augment those already available.

M. A. Grossmann (23)[1] gives a complete discussion of the relation of machinability to hardness and workability. He states that "by workability is understood the capacity of a material for undergoing plastic deformation without rupture. The elongation in a tension test, the extent of bending before fracture in the notch-impact and various cold-bend tests, and the extent of deformation in the other mechanical tests all represent this quality of work-

[1]The figures which appear in parentheses have reference to the bibliography appended to this paper.

ability." After explaining Thieme's conception of chip removal, which is a pressure process, he adds, "There comes into question not only the resistance to penetration, but also the resistance to the pressing aside of the chip element," and concludes with, "we arrive thus at the law that machinability depends on both hardness (e. g., ball hardness)and workability, the difficulty of machining increasing with an increase in either property." It is explained that the test may be carried out on a planer, lathe, or drill press, all factors constant so that the travel of the tool for a given force on it in a specific time, is the measure of machinability.

Force on Tool, or Power Absorbed

The force on a tool of standardized shape, or the power absorbed by the tool while cutting various metals as outlined under methods

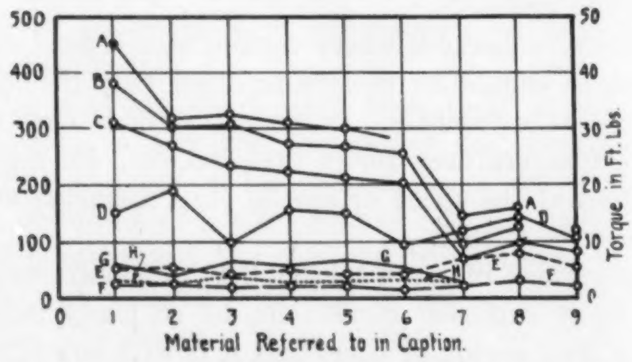

Fig. 1—Machinability and Physical-Property Curves. Curves: A, Torque in Ft. Lbs. B, Unit Force for 0.5 by 0.012 In. Chip 15-Degree Front-Rake Tool. C, Unit Force for 0.5 by 0.012 In. Chip 30-Degree Front-Rake Tool. D, Brinell Hardness Number. E, Rockwell Hardness Number. F, Scleroscope Hardness Number. G, Percentage Reduction of Area (Tension). H, Percentage Elongation in 2 Inches. Materials: 1, 1.03 Per Cent Carbon Steel, Bar No. 32. 2, S. A. E. 2345 Steel, Bar No. 29. 3, 0.15 Per Cent Carbon Steel, Bar No. 4. 4, S. A. E. 2320 Steel, Bar No. 30. 5, S. A. E. 3120 Steel, Bar No. 31. 6, S. A. E. 1035 Steel, Bar No. 28. 7, Brass, Rolled, Bar No. 26. 8, Cast Iron, Unannealed, Bar No. 8. 9, Cast Iron, Annealed, Bar No. 8A.

1 and 2 has been used in a number of instances as an indication of the relative machinability of metals. Work along this line has been done at the University of Michigan (35), in which eight different metals were used. The metals with their physical and chemical properties are referred to in Table I of that article.

Fig. 1 shows the physical properties such as hardness numbers on the Brinell, scleroscope, and Rockwell, per cent reduction of area, and per cent of elongation in 2 inches, plotted as ordinates over the material number. The material number or abscissa, such

as 1, 2, 3, etc., represents the various materials referred to in the table in the figure. These materials are representative of all those cut and are arranged in the order of their degree of machinability. Curve A represents the torque in foot-pounds, produced by a 1-inch diameter twist drill having a helix angle of 28 degrees, and a clearance angle of 6 degrees, while rotating at 94 revolutions per minute with a feed of 0.006 inches per revolution. This was recorded on the previously calibrated mercury column

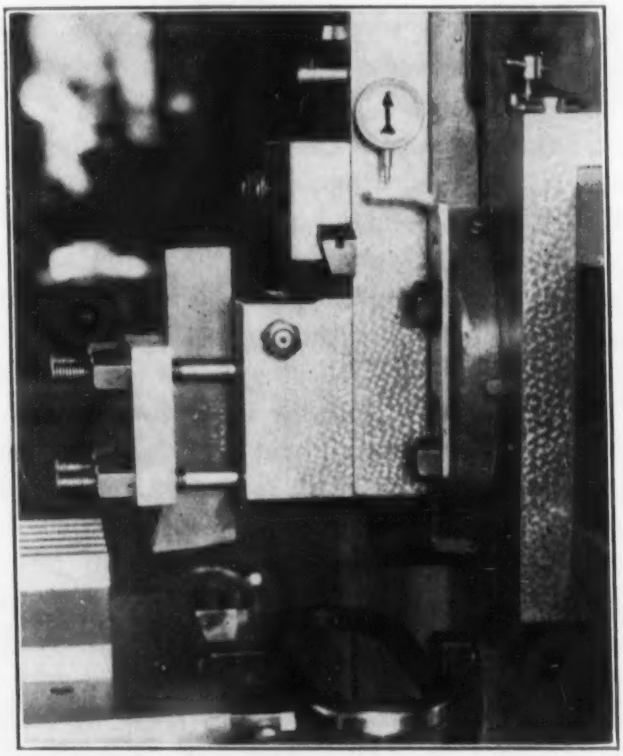

Fig. 2—Arrangement of Planer Tool for Determining Machinability.

gage of a drill dynamometer built at the University. The carbon steel drill was ground on a Blau drill-grinder and was subsequently honed. It retained its keen cutting edge throughout these tests. Curve B represents the unit force, i. e., pounds per 0.001 square inch of cross sectional area of the chip as removed by a planer tool while cutting in a straight line approximately 3 feet long. The chip was 0.5-inch wide and 0.012-inch deep. The tool was of the end-cutting type having a 4-degree clearance and 15-degree front-rake angle. It had no side-rake angle. For each stroke of the

planer table, the tool was fed vertically downward the 0.012-inch as measured by a dial gage mounted on the tool head, as shown in Fig. 2. The width of the chip was previously determined by milling slots the length of the test bar, which left lands, also shown in Fig. 2 and Fig. 20. The unit force, i. e., the force in pounds per 0.001 square inch of cross sectional area of the chip was selected so that all results would be comparable. The size and shape of the chip in all instances is identical, so as to eliminate any influence of chip shape. Curve C represents the unit force on the tool for the same conditions as those for curve B, with the exception that the front-rake angle of the tool was 30 degrees instead of 15 degrees. Curve D represents the Brinell hardness numbers of the materials; E, the Rockwell hardness numbers; F, the scleroscope hardness numbers; G, the percentage of reduction of area in tension; and H, the percentage of elongation in two inches.

All of the steels referred to in Fig. 1 were in an annealed state. For other heat treatments of the materials, the unit forces and hardness numbers would probably be different. While the drill torque and unit force on the planer tool curves follow in general the same tendencies, there appears to be no helpful relation between the force curves and the hardness number curves. The highest point on the Rockwell and scleroscope hardness curves is for cast iron, 8. The per cent reduction of area appears to be highest for the steels which have the lowest unit force, except the S. A. E. 2345 steel, 2, but drops with the unit force for brass, 7, as the unit forces and torque also do. No relation between the unit forces, torqúe, and these factors seems to be suggested.

Other values of drill helix or even front-rake angle of the planer tools might have been used and more favorable results obtained. This seems doubtful, however, because of the general tendency of the unit forces to vary directly as the front-rake angle is changed.

To show more clearly the influence of the front-rake angle on the unit force values, Fig. 3 is presented, in which brass, soft-rolled, bar No. 24, was cut. The front-rake angle of the tool was varied in different cuts from 0 to 30 degrees. It is seen that for a depth of cut of 0.012-inch the unit force is reduced from 125 pounds for the 0 degrees front-rake tool to about 82 pounds for the 30-degree front-rake tool. For the thinner chip, that having a depth of cut of 0.006 inch, the width remaining the same, it is seen that the

unit forces are constantly higher than for the thicker chips; also that the unit force is reduced less for the same increase in front-rake angle when the front-rake angle is large. Fig. 4 shows that this same relation holds for cast iron, as beyond the 30-degree front-rake angle there appears to be little reduction in unit force for an increase in front-rake angle. Further, it appears that beyond 45-degree front-rake the unit force is increased with further

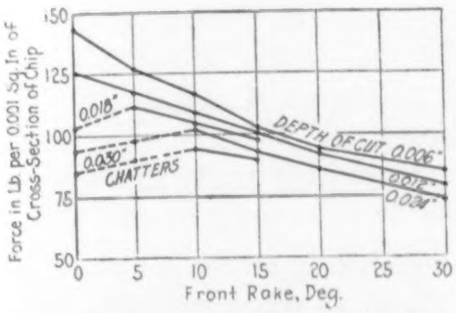

Fig. 3—Unit Force—Front Rake Angle Curves for Brass. Material: Brass, Bar No. 24. Tools: 4-Deg. Clearance. Width of Cut: 0.506 In. Speed: 20 Ft. Per Min.

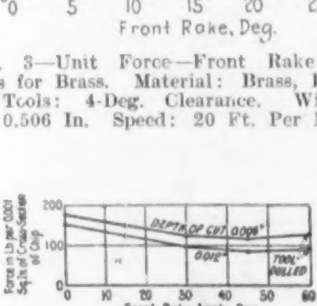

Fig. 4 — Unit Force — Front Rake Angle Curves for Cast Iron. Material: Cast Iron, Unannealed. Bar No. 1. Tools: 4-Deg. Clearance. Width of Cut: 0.5 In. Speed: 20 Ft. Per Min.

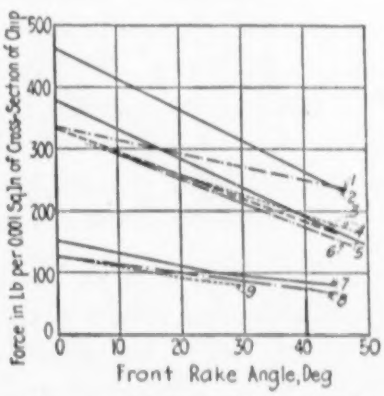

Fig. 5—Summary Unit Force—Front Rake Angle Curves. Tools: 4-Deg. Clearance. Depth of Cut: 0.012 In. Width of Cut: 0.5 In. Speed: 20 Ft. Per Min. Curve 1: S. A. E. 2345 Steel, Bar No. 29. Curve 2: 1.03 Per Cent Carbon Steel, Annealed, Bar No. 32. Curve 3: S. A. E. 3120 Steel, Bar No. 31. Curve 4: S. A. E. 2320 Steel, Bar No. 30. Curve 5: 0.15 Per Cent Carbon Steel, Annealed, Bar No. 3. Curve 6: S. A. E. 1035 Steel, Bar No. 28. Curve 7: Cast Iron, Unannealed, Bar No. 9. Curve 8: Cast Iron, Annealed, Bar No. 9A. Curve 9: Brass, Bar No. 24.

increase in front rake. This relation was found to hold with all of the materials cut with these large front-rake angles.

Fig. 5 is a summary sheet showing the influence of the front-rake angle on the unit forces for all materials cut with a depth of cut of 0.012-inch. It is quite obvious from these results that the relation follows the straight-line law and the force on the tool is reduced as the front-rake angle is increased, till a certain limiting angle is reached. Beyond this angle, which seems to be between 20 and 30 degrees for brass, 25 to 30 degrees for cast iron, and above 45 degrees for steel, the influence of the front-rake angle, is less pronounced. The unit forces of some metals are influenced more readily by the front-rake angle than others, i. e., the per cent reduction in the unit force for a given increase in front-rake is

greater for some metals than others. From these curves, the unit forces for any front-rake angle under these standardized conditions may be selected.

It was found that if the depth or width of cut was varied, there was a distinct influence on the unit force. Fig. 6 shows the

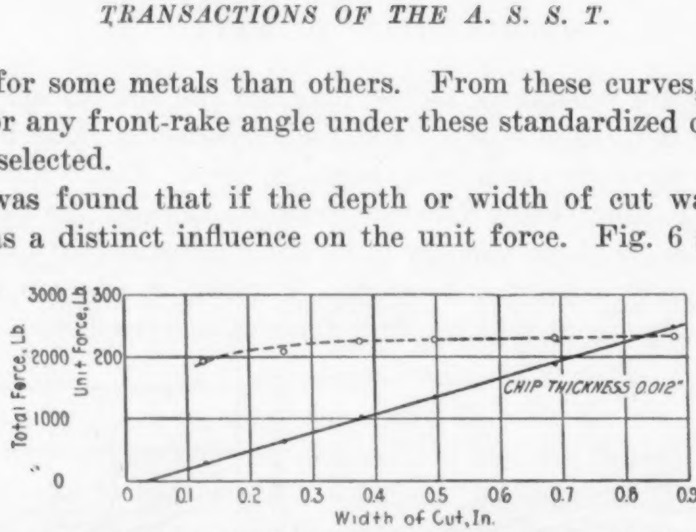

Fig. 6—Unit and Total Force—Chip Width Curves. Material: S. A. E. 2320 Steel, Bar No. 30. Tool: 4-Deg. Clearance, 30-Deg. Front Rake. Speed: 20 Ft. Per Min.

total and unit forces on the tool when cutting at a speed of 20 feet per minute and taking a chip the depth of which was constant at 0.012-inch, while the width of the cut was varied. The material was S. A. E. 2320 steel and the results are representative for all of the materials cut. The solid line represents the total force on the

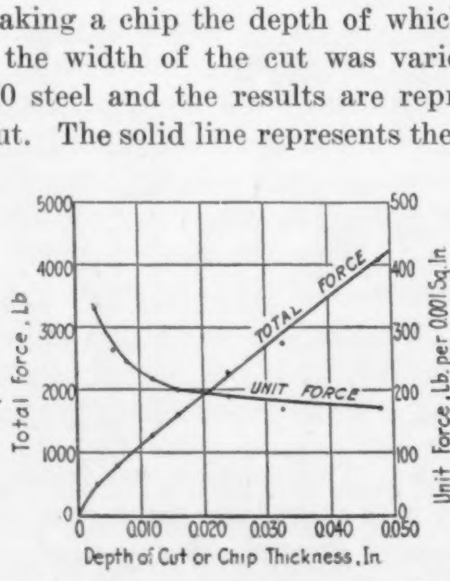

Fig. 7—Unit and Total Force—Chip Thickness Curves. Material: S. A. E. 3120 Steel, Bar No. 31. Tool: 4-Deg. Clearance, 30-Deg. Front Rake. Width of Cut: 0.5 In. Speed: 20 Ft. Per Min.

tool for each width of cut. It appears to be a straight line which passes slightly to the right of the origin on the abscissa axis. Actually, of course, the curve would have to turn concave upward at the lower left end where no experimental points are available so as to pass through the origin to give a zero force on the tool when the width of cut is zero. The dashed line shows the unit

force for each width of cut. The unit force is obtained by dividing the total force by the cross sectional area of the chip times 1000. It is seen that if the total-force curve must be concave upward to pass through the origin, the unit-force curve is concave downward. In other words, the unit force is reduced for the narrower widths of cut. This condition was found in all of the materials. No explanation is offered, although a mathematical expression was developed to express the relation. All steel chips were noticed to have on the under side which slides over the tool face a narrow band at either edge which appeared somewhat smoother than the surface in between. This band was approximately 1/32 of an inch wide. It was thought the intensity of stress due to the removal of the chip by the tool was less on these two narrow bands than on the portion of the chip between them.

Fig. 7 shows a total- and unit-force curve as a function of the depth of cut for S. A. E. 3120 steel. The width of cut was constant at 0.5-inch and the speed 20 feet per minute. Again the 30-degrees front-rake tool was used. This curve is representative of all materials cut in that the total-force curve is concave downward with the greatest curvature at the lower left end so as to make it pass through the origin when the area of chip is zero. The unit-force curve in all cases shows a distinct tendency to rise for the thinner chips. For steel the greatest increase in the unit-force curve is for the chips below 0.024-inch thickness. For cast iron and brass, this abrupt increase occurs when the depth of cut or thickness of chip is much less, or about 0.012-inch. For a chip thickness of 0.003-inch, the unit force is 330 pounds, equivalent to 330,000 pounds per square inch or nearly 100,000 pounds greater than the ultimate strength of tension, compression, and shear combined.

The torque and unit-force curves shown as A, B, and C in Fig. 1 are reproduced in Fig. 8 with other physical property curves. The abscissas refer to the materials given in the caption of Fig. 1. Curve D represents the elastic limits in tension for each material. The elastic limit for the 1.03 per cent carbon steel, 1, is 39,170 pounds, which is lower than that for steels 2, 4, and 5 while its corresponding unit-force value is highest of all steels. The elastic limits of bars Nos. 3 and 6, both low carbon steels, are relatively low, while the respective unit forces are even with those of the other steels. The elastic limit for brass, 7, is not altogether

reliable, although it was determined as carefully as possible. Curve F represents the elastic limits in compression for the material and follows closely curve D, the elastic limit in tension. Curves E, G, and H represent the ultimate strengths (maximum load divided by original area) in tension, compression, and shear, respectively. These curves show high values for the alloy steels 2, 4, 5, and relatively low values for the carbon steels 1, 3, and 6, and indicate no consistent relation to the cutting unit-force curve. The ultimate strength curves G and E show a reduction for annealed and unannealed cast iron, which is not proportional to the reduced cutting-forces of curves A, B, and C. The elastic limits and ultimate strengths in tension, curves D and E, are relatively high for brass, 7, however, which has the lowest cutting unit force. Figs. 1 and 8 indicate no consistent relation between the physical properties of the various metals and the unit forces. They do suggest, however, that it may be of advantage to divide the materials into four groups, namely, alloy steels, carbon steels, brass, and cast iron for further study. Such an investigation is now under way at the University. A study is being made of the machinability of the cast irons containing various proportions of charcoal irons, cast irons containing various proportions of silicon, and cast irons containing various proportions of sulphur. This work is not yet ready for publication.

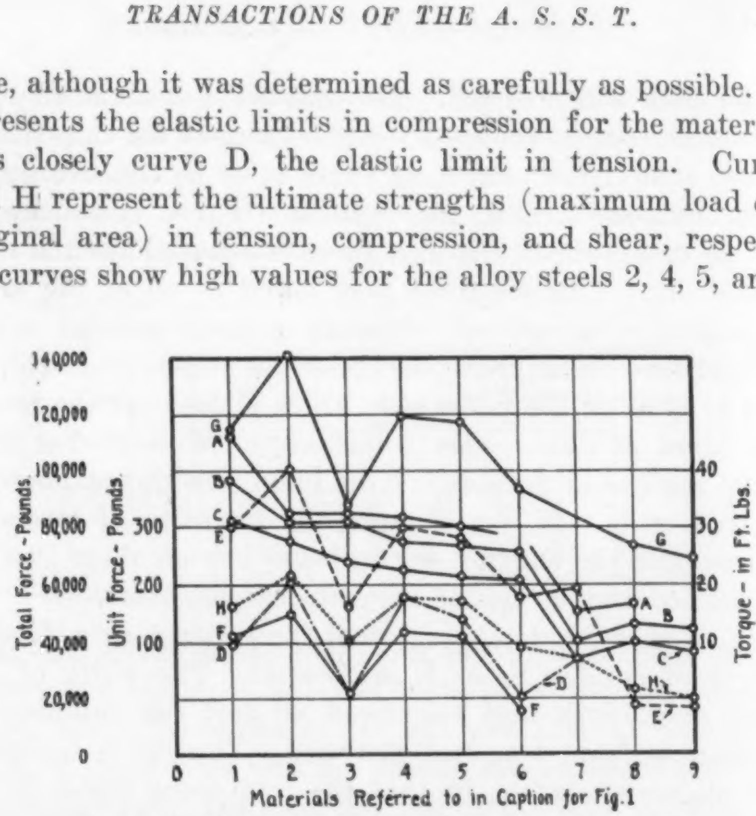

Fig. 8—Machinability and Physical-Property Curves. Curves: A, Torque in Ft. Lbs. B, Unit Force for 0.5 by 0.012 In. Chip 15-Deg. Front-Rake Tool. C, Unit Force for 0.5 by 0.012 In. Chip 30-Deg. Front-Rake Tool. D, Elastic Limit (Tension). E, Ultimate Strength (Tension). F, Elastic Limit (Compression). G, Ultimate Strength (Compression). H, Ultimate Strength (Shear).

Figs. 9 to 17, inclusive, show the location of each material on the coordinate axes. The ordinates equal the unit cutting force on the planer tool for the material, and abscissas equal the physical properties in question. In all cases, the solid line represents the unit forces for the 30-degree front-rake tool, and the dashed line

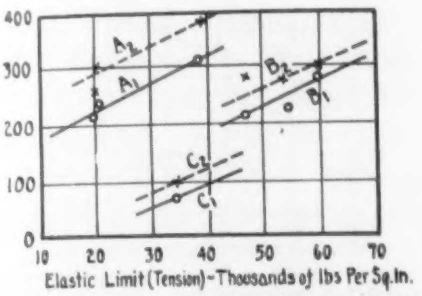

Fig. 9—Unit Force—Elastic Limit (Tension). Tools: 4-Deg. Clearance, 30-Deg. Front Rake. 4-Deg. Clearance, 15-Deg. Front Rake. Chip: 0.012 In. Deep by 0.5 In. Wide. Speed: 20 Ft. Per Min. Bar No. 32: 1.03 Per Cent Carbon Steel. Bar No. 29: S. A. E. 2345 Steel. Bar No. 4: 0.15 Per Cent Carbon Steel. Bar No. 8: Cast Iron, Unannealed. Bar No. 30: S. A. E. 2320 Steel. Bar No. 31: S. A. E. 3120 Steel. Bar No. 28 S. A. E. 1035 Steel. Bar No. 8A: Cast Iron, annealed. Bar No. 26: Brass, Rolled.

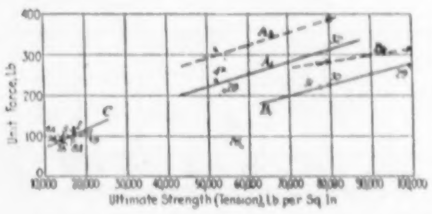

Fig. 10—Unit Force—Ultimate Strength (Tension). Tools: 4-Deg. Clearance, 30-Deg. Front Rake. 4-Deg. Clearance, 15-Deg. Front Rake. Chip: 0.012 In. Deep by 0.5 In. Wide. Speed 20 Ft. Per Min. (Material Bar Numbers Same as in Fig. 1).

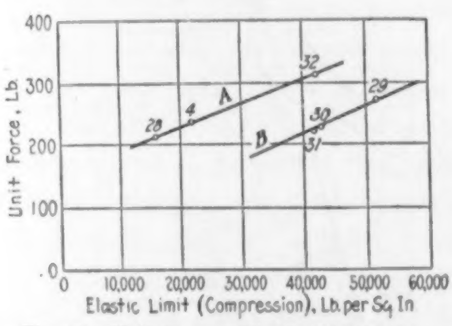

Fig. 11—Unit Force—Elastic Limit (Compression). Tools: 4-Deg. Clearance, 30-Deg. Front Rake. Chip: 0.012 In. Deep by 0.5 In. Wide. Speed: 20 Ft. Per Min. (Material Bar Numbers Same as in Fig. 1.)

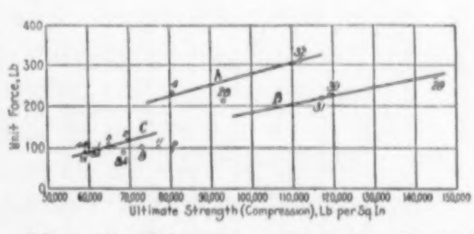

Fig. 12—Unit Force—Ultimate Strength (Compression). Tools: 4-Deg. Clearance, 30-Deg. Front Rake. Chip: 0.012 In. Deep by 0.5 In. Wide. Speed: 20 Ft. Per Min. (Material Bar Numbers Same as in Fig. 1.)

those for a 15-degree front-rake tool, each having a 4-degree clearance angle. The size of chip in each case was 0.012-inch deep by 0.5-inch wide and the speed was 20 feet per minute. The number of each point refers to the bar number in the caption of Fig. 1.

Fig. 9 shows the points plotted over the elastic limits in tension as abscissas. Bars 28, 4, and 32, which are all straight carbon steels, lie close to the straight line A1 or A2, while bars 31, 32,

and 29, which are alloy steels, indicate lines B1 and B2. For the brass, 26, an independent line C is indicated. In Fig. 10, the points are plotted over the ultimate strengths in tension. Again, the straight carbon steels, 4, 28, and 32, indicate the possibility

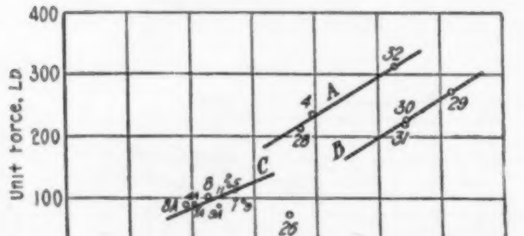

Fig. 13 — Unit Force — Ultimate Strength (Shear) Tools: 4-Deg. Clearance, 30-Deg. Front Rake. Chip: 0.012 In. Deep by 0.5 In. Wide. Speed: 20 Ft. Per Min. (Material Bar Numbers Same as in Fig. 1.)

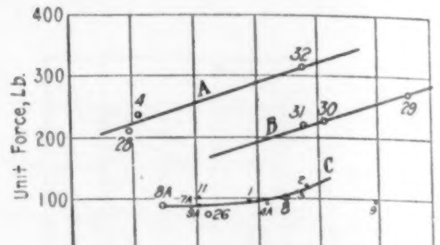

Fig. 14—Unit Force—Brinell Hardness Numbers. Tools: 4-Deg. Clearance, 30-Deg. Front Rake. Chip: 0.012 In. Deep by 0.5 In. Wide. Speed: 20 Ft. Per Min. (Material Bar Numbers Same as in Fig. 1.)

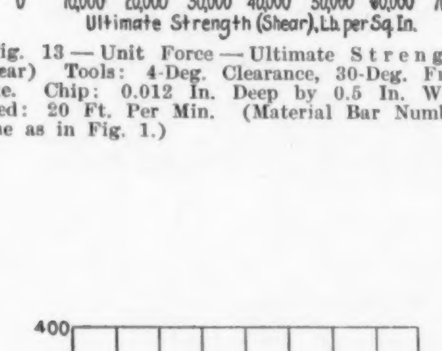

Fig. 15—Unit Force—Scleroscope Hardness Numbers. Tools: 4-Deg. Clearance, 30-Deg. Front Rake. Chip: 0.012 In. Deep by 0.5 In. Wide. Speed: 20 Ft. Per Min. (Material Bar Numbers Same as in Fig. 1).

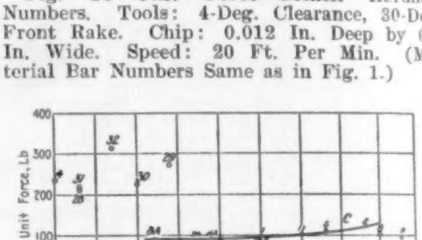

Fig. 16—Unit Force—Rockwell Hardness Numbers. Tools: 4-Deg. Clearance, 30-Deg. Front Rake. Chip: 0.012 In. Deep by 0.5 In. Wide. Speed: 20 Ft. Per Min. (Material Bar Numbers Same as in Fig. 1).

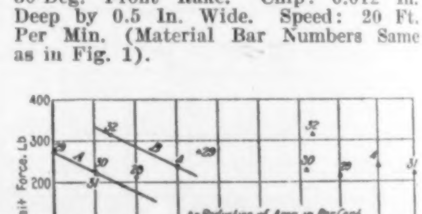

Fig. 17—Unit Force—Elongation and Percentage of Reduction of Area. Tools: 4-Deg. Clearance, 30-Deg. Front Rake. Chip: 0.012 In. Deep by 0.5 In. Wide. Speed: 20 Ft. Per Min. (Material Bar Numbers Same as in Fig. 1.)

of curves A1 and A2, while the alloy steels 29, 30, and 31 indicate the possibility of curves B1 and B2. Points for cast iron, bars 1, 2, 4A, 5, 7A, 8, 8A, and 9A are concentrated in a group by themselves, which suggests the line C.

Fig. 11 shows the points plotted over the elastic limit in com-

pression, and Fig. 12, the same over the ultimate strength in compression. In each case, a curve A through the carbon steels is indicated, and also a curve B through the alloy steels. In Fig. 12, the available data for cast iron are again plotted on the ultimate strength in compression and a possible curve C is suggested as a continuation of curve B. The curve C, however, might almost as well be horizontal, indicating no relation between machinability and ultimate strength. Fig. 13 shows the points plotted over the ultimate strength in shear and the curves A, B, and C seem to be clearly indicated. Again the curve C might be shown to become a part of curve B extended, were more data available. The point for brass, 26, seems to be quite independent.

Values of the unit forces for the various materials are plotted over the Brinell, the scleroscope, and the Rockwell hardness numbers in Figs. 14, 15, and 16, respectively. The Brinell numbers seem to indicate the line A through the carbon steels 28, 4, and 32. and another line B through the alloy steels, 31, 30, and 39. The points for cast iron show the same unit-force values over a range of Brinell hardness numbers from 110 to 150, but the unit force increases perceptibly as the Brinell numbers increase above 150. The value of curve C is, therefore, questionable.

The scleroscope hardness numbers shown in Fig. 15 seem to group the steels together in one group and the brass and cast irons together in a second. There appears to be no relation which would predict the unit force value for a given scleroscope hardness for the steels, but curve C through the points for cast iron is indicated. Because of the slight slope, this would be of little value as an indication of machinability. There seems to be no useful relation between the unit-force plotted over Rockwell hardness numbers as shown in Fig. 16. The points for steel are well scattered and the curve C through cast iron is nearly horizontal.

In Fig. 17 are shown plotted for each material the unit forces as ordinates over the reduction of area in per cent, and elongation in 2 inches in per cent as abscissas. The reduction of area points cover the whole field from 32 per cent for brass, 26, to 70 per cent for S. A. E. 3120, 31. The percentage of elongation points are well grouped together to the left in the figure. Line A has been drawn through the points for the alloy steels 29, 30, and 31 and may represent a relation between the elongation and the unit cutting forces. A similar relation is not so apparent, however, for the

carbon steels, as point 28 falls too far below line B drawn through points 32 and 4.

The deductions made above have been made in most cases for only three points for each line. Unquestionably, additional data for both carbon and alloy steels would permit more definite conclusions to be drawn. The fact that the straight carbon steels seem to separate themselves from the alloy steels as far as their

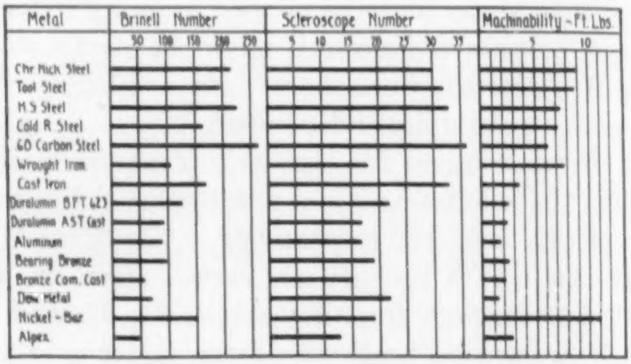

Fig. 18—Machinability of Metals as Determined by Energy Absorbed by Single Tooth Milling Cutter. (Carl Oxford.)

cutting properties are concerned, is new to the author and appears to be a problem of atomic or crystalline structure of the metals. This suggested the use of the slow-motion picture machine. Only recently slow-motion pictures have been taken of differently shaped tools cutting an alloy steel, carbon steel, cast iron, and brass at speeds of 2 and 20 feet per minute, while both thin and thick chips were being removed. Unfortunately these pictures are not available at this time for presentation.

Variations in the Cutting Force with the Speed of Cutting

Smith and Hey (14) made some experiments to determine the influence of the cutting speed on the vertical force on the tool. Various tools having a 60-degree cutting angle were used in cutting medium carbon steel at speeds varying from 8 to 160 feet per minute without withdrawing the tool. At each successive speed, as it was increased in stages from minimum to maximum, the vertical force on the turning tool was measured. The results show that for a speed of 8 feet per minute the vertical force is relatively low. The speed increases abruptly 15 per cent when the speed is 20

feet per minute and shows an increase to a maximum about 28 per cent when the speed is 38 feet per minute. Beyond this point, the vertical force is gradually reduced as the speed is increased until for the range between 100 and 160 feet per minute, it equals that for 8 feet per minute. This shows that, for the lower speed ranges, the variation in force is greatest, while for the higher speed ranges (above 100 feet per minute) the variation is nil. In the author's work, many identical cuts with the same tool were run at 20 and 35 feet per minute respectively. In every instance, other factors remaining constant, the forces in the direction of cut on the planer tool for the two speeds were found to be identical. The two speeds referred to are near the crest of Smith and Hey's curve, so that the results apparently agree.

The Force on the Tool or Power Absorbed as a Function of Chip Size and Shape, and Cutting Speed

Taylor developed the formula for pressure on a tool as $P = CD^{14/15}\ F^{3/4}$, in which C equals a constant depending on the material being cut and the tool used, D equals the depth of cut, and F equals the feed.

French and Digges (31) represent the power absorbed by the tool as $P = KFDS = KAS$, in which K is a constant for the particular size and form of tool used and properties of the steel cut, F is the feed, D is the depth of cut, S is the speed, and A equals FD the area of cut. This equation applies for steel containing 0.3 per cent carbon and 3½ per cent nickel when heat treated to show a tensile strength of about 100,000 pounds per square inch. They state, however, that since the measurements themselves are subject to considerable fluctuation, duplicate runs sometimes differing by 10 or 15 per cent in power consumption, a high degree of accuracy in predicting power requirements cannot be expected.

French and Digges modified this equation to suit a wide variety of steels to read as follows: $P = mKAS = mKFDS$, in which m is the ratio of the slope of the power-cutting speed line for any steel to that of the 3½ per cent nickel steel mentioned above. From experimental data the values of m were determined for four steels, one softer and two harder than the nickel steel. The value was then plotted over the tensile strength of each steel as abscissa. The equation for the m tensile strength line was found to be

$$m = 1 + \frac{4.5}{100{,}000}(T - 100{,}000) = \frac{4.5T - 350{,}000}{100{,}000}$$

in which T equals the tensile strength in pounds per square inch. A chart, Fig. 19 showing the relation between the depth of cut, the feed, cutting speed, and power in kilowatts for their standard tool when cutting the nickel steel was prepared. By using the proper

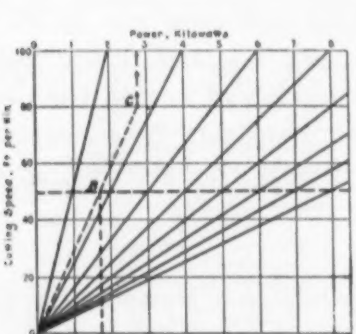

Fig. 19—Power Chart (French and Digges). This Gives an Approximate Determination of Power Required in Cutting, with a Tool of ½ Inch by ¼ Inch High Speed Steel Having 6-Deg. Clearance, 8-Deg. Side Rake, 14-Deg. Front Rake, and ⅛ In. Nose Rad. at Different Speeds, Feeds, and Depths, 3½ Per Cent Nickel Steel with Tensile Strength of About 100,000 Lbs. Per Sq. In.

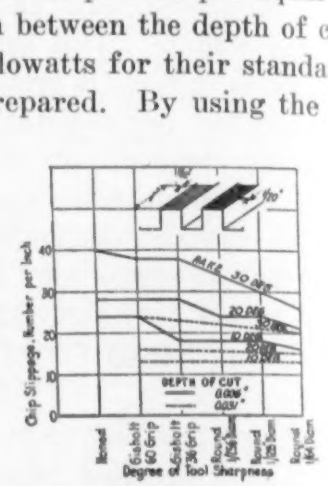

Fig. 20—Chip Slippage—Tool Sharpness Curves. Material: 0.15 Per Cent Carbon Steel, Annealed. Tools: 4-Deg. Clearance.

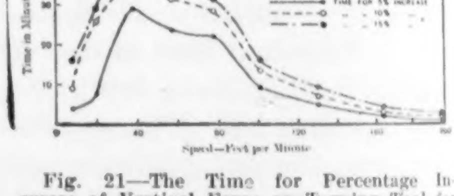

Fig. 21—The Time for Percentage Increase of Vertical Force on Turning Tool for Finishing Cuts at Different Speeds. (D. Smith.)

values of m for another steel, as shown in the modified equation, the power to cut that material may be determined.

This straight line equation does not agree with the results of the author as pointed out above in Figs. 6 and 7 in which the force varies with the width and depth of cut. The modified equation involving m or the tensile strength as a straight line function agrees with the results of the author when the cut is constant, but it would apply to carbon steels in one group and alloy steels in another.

To find the power required in cutting at, say, 80 feet per

minute with 0.028-inch feed and 0.15-inch depth of cut with the tool referred to making use of French and Digges' power chart, Fig. 19, the point A is first located as a function of the feed and depth of cut, and projected upward as shown till it intersects the 50 feet per minute speed line at B. The power numbers given at the top are in terms of the 50 feet speed for the nickel steel. A line drawn through the origin O and the intersecting point B intersects the cutting speed of 80 feet per minute at C. Vertically above C is read the power in kilowatts for cutting the nickel steel.

In discussing French and Digges' paper, T. H. Wickenden states that "in one set of tests the power consumption under certain standardized conditions of feed and speed was taken as an index of the relative machinability of different alloy steels. Steels tested came within the following S. A. E. steel specifications:

2340—3½ per cent nickel steel
3140—chromium-nickel steel
4140—chromium-molybdenum steel
5140—chromium steel
6140—chromium-vanadium steel

These steels were all heat treated to secure approximately an equal Brinell hardness of around 310. Samples of the various steels were turned with the same tool and the power required in each case was determined, after which the order of machining the samples was reversed. The average result of 49 tests showed that machining the 3½ per cent nickel steel consumed the least amount of power, while the chromium-molybdenum steel consumed the greatest amount of power, amounting to about 10 per cent more power than the 3½ per cent nicked steel. No data were secured on tool life in these tests. The carbon content of the chromium-molybdenum steel was toward the upper limit of the specifications, which might account for some of the difference, although the steels were so heat treated that the tensile strengths were almost identical."

The Energy Absorbed by a Milling Cutter

In Fig. 18 is shown the machinability of a number of different metals as determined by Carl Oxford. By machinability in this case, is meant the energy measured in foot-pounds required to remove a chip of a given metal by a single tooth milling cutter which takes a cut 1/8-inch wide and a feed per chip of 0.012-inch for a constant depth of cut. The radius of the cutter was 1-3/4-inch. The machinability tester is described in Airey and Oxford's paper

on "The Art of Milling." The Brinell and scleroscope numbers for each material are also given. It is seen, for instance, that the machinability of nickel is greatest of all, being 11 foot pounds, for which the Brinell and scleroscope numbers are 150 and 19, respectively. For a 0.60 per cent carbon steel, the Brinell and scleroscope numbers are 254 and 36 respectively, while the machinability is but 6.3 foot-pounds. This illustration is named to show the lack of uniformity in the relation between the three measurements.

The Ability of a Tool to Cut

The ability of a standardized tool to cut various metals is probably the most practical index for determining the relative machinability of metals, as the shop man is interested in whether or not the material can be machined readily. It has been shown by Taylor, Dempster Smith, and French and Digges (31) that the relation between tool life and cutting speed is VT^n equals a constant, in which V represents the cutting speed in feet per minute, T, the life of the tool before breakdown in minutes, and C, a constant depending on the tool used and the material being cut. For steel, Smith found experimentally the value of N to equal 1/8, which checked Taylor's results. French, however, found that a value of 1/7 satisfied his experimental data to better advantage. Barth has used a value of 1/12 when cutting cast iron. With the use of this equation, the ability of a standardized tool to cut may be expressed, (a) in terms of the life of the tool for a given cutting speed or, (b) in terms of the cutting speed for a definite tool life. The "Taylor speed," or the cutting speed required to cause a tool to fail in 20 minutes seems to be used generally for this purpose as being a means of determining in a short time the machinability of a metal. A cutting speed corresponding to a more practical tool life may be determined, using the above equation.

Taylor found that the relation between cutting speed for a tool life of 20 minutes when cutting steel, and the feed, depth of cut, and radius of the nose of the tool, could be closely represented by the general formula

$$V = \frac{\text{Constant} \times \left(1 - \frac{8}{7(32r)}\right)}{F^{\frac{2}{5}} + \frac{2.12}{5 + 32r}\left(\frac{48D}{32r}\right)^{\frac{2}{15}} + 0.06\sqrt{32r} + \frac{0.8(32r)}{6(32r) + 48D}}$$

in which V = cutting speed in feet per minute for a 20 minute tool life; F, the feed per revolution in inches; D, the depth of cut in inches; r, the nose radius of the tool in inches.

Taylor reduced this formula to fit all of his standard tools. For the $\frac{5}{8}$-inch tool, for which r = 5/32 inches, the general equation above becomes

$$V = \frac{\text{Constant} \times 0.954}{F^{0.612}\left(\frac{48D}{5}\right)^{0.2675 + \frac{4}{30 + 48D}}}$$

With the steel available, the value of the constant was determined experimentally so that the numerator of the above equation for the $\frac{5}{8}$-inch tool becomes 20.77.

With this equation, then, the value of V may be determined for any combination of feed and depth of cut for the $\frac{5}{8}$-inch tool having a clearance angle of 6-degrees, front-rake 8-degrees, and side-rake 14-degrees.

Taylor further found that the general equation applied also to cast iron and that for the $\frac{5}{8}$-inch tool referred to above, the equation for cutting cast iron becomes

$$V = \frac{65.4}{(20F)^{0.5853 - \frac{0.3}{1 + 100F}}\left(\frac{32D}{5}\right)^{0.2182 + \frac{0.27}{3 + 32D}}}$$

The general equation has recently been checked at the Bureau of Standards and found to give very close results with present day high-speed steel tools when cutting steels of a wide variety (31).

Increase Tool Life by Adding Nickel to Gray Cast Iron

The International Nickel Company recently has conducted experiments to show the advantages of adding nickel and chromium to gray cast iron. The fundamental feature of the benefit which nickel confers upon gray cast iron with respect to machinability is the unusual dual effect of nickel on iron; namely, to precipitate excess graphite or to "gray" the iron, while at the same time to strengthen the iron and harden the matrix. White iron which frequently occurs on the edges and corners of castings due to too sudden cooling offers increased resistance to the cutting tool, usually destroying the cutting edge. When the silicon content of the iron is raised in order to eliminate these white edges, the body

of the casting becomes coarse grained, soft, and weak. If nickel is used to "gray" these white edges instead of silicon, the casting is made completely machinable without detriment to the strength and hardness of the thicker section.

Quoting from this report: "gray cast iron consists structurally of a matrix of iron (combined with some carbon) within which are soft graphite flakes and hard, free carbide particles in the case of hard irons. Its hardness depends not only on the intrinsic hardness of that matrix, but upon the amounts and distribution of graphite and carbides as well. When a soft iron is desired, the foundryman uses a higher silicon content and thereby increases the amount of soft graphite and eliminates the hard carbides. When he wishes to secure increased hardness in his castings, however, he lowers the silicon content and secures it by diminishing the amount of soft graphite flakes and increasing the amount of hard carbides. The matrix of the iron (pearlite) remains substantially the same in either case and relatively soft intrinsically.

"The distinctive feature of hardening gray iron by nickel is that this is accomplished by a progressive and uniform hardening of the iron matrix (producing sorbite) instead of through increase in the amount of hard carbides."

It is shown that the machinability can be improved by using higher silicon irons, but with attendant and progressive impairment of physical properties. When these may not be sacrificed, nickel should be used, as it will improve machinability and at the same time progressively improve physical properties.

Further, Wickenden and Vanick in discussing the effect of nickel and nickel-chromium in cast iron, state "nickel and nickel-chromium cast iron is being used commercially today for rolling mill parts such as rolls, mill guides, pipe bending dies, pipe balls, etc., for automobile engines and other cylinder castings, for pistons and piston rings, for cast iron cams, for sheet and plate metal forming dies, in various thin section castings, prominently resistance grids—the amounts used varying from as little as 0.10 per cent (but usually not less than amount 0.40 per cent) up to 5.0 per cent nickel and from 0 to 0.50 per cent chromium.

"The principal useful effects of nickel and suitable nickel-chromium combinations in gray iron have proved to be: (1) To increase strength from 10-50 per cent, requiring 0.50 to 1.0 per cent nickel together with 0 to .50 per cent chromium depending on the

grade of iron,—a higher silicon iron requiring a greater addition of chromium; (2) to increase hardness 20 to 50 points Brinell without impairing machinability, requiring similar amounts of alloy; or raising the hardness 100 points Brinell, with the iron still remaining machinable, but less readily so, with large amounts of alloy; (3) to reduce edge, surface, and corner chilling on thin sections or eliminate hard spots in castings made with comparatively hard iron and thus improve machinability; requiring from 0.50 to 5 per cent nickel depending on conditions; (4) to increase toughness and deflection particularly of thin section castings by eliminating chill and hard spots, requiring also from 0.50 to 5 per cent nickel; (5) to refine grain and produce denser, less open castings requiring from 0.15 to 1.0 per cent nickel together with small amounts of chromium if desirable; (6) to equalize hardness and strength and machinability over large sections or between small irregular sections."

Table I shows their lists of some present typical commercial uses of nickel and nickel-chromium cast iron.

Increase Tool Life by Annealing Cast Iron

Priester and Curran (37) conducted tests on gray cast iron to show the influence of annealing on machinability and other mechanical properties. Cast iron pistons were used. Tests were run on one set of pistons annealed and on the second set unannealed. All cuts were taken with a ground No. 3 Stellite tool bit flooded with a heavy stream of specially prepared coolant. The machining tests show a decided advantage in favor of the annealed casting. The ratios obtained in the rough skirting and turning of the annealed and unannealed castings were 2 to 1 and 6 to 1, respectively. The average endurance of the tool in the finish turning operation was in the ratio of 13 to 1 in favor of the annealed piston. In the rough turning of the ring grooves, the ratio was 3 to 1, and for finish turning, 5 to 1 in favor of the annealed castings. It is stated that this large variation was due to the favorable condition of the internal structure produced by the annealing processes.

Finish as a Function of Machinability

Many times the finish left by a cutting tool or an abrasive is a very important criterion of the machinability of a metal.

Table I

Commercial Uses of Nickel and Nickel-Chromium Cast Iron

Article	Alloy	Reason for Adding Alloy
Thin Section Resistance Grids	5 per cent Nickel	To improve toughness.
Thin Section Piston Rings	⅓ per cent Nickel	To improve toughness, machinability, and resistance to wear.
Pistons	¾-1½ per cent Ni	To improve machinability and resistance to wear.
Automobile Cylinders and Sleeves	Ni 2 per cent Ni 1.0 per cent Cr 0.3 per cent	To improve density and resistance to wear.
Cams	3 per cent Nickel	To secure maximum hardness still machinable.
Rolls	1.50 per cent Ni 0.75 per cent Cr	To secure strength, toughness.
Pipe-balls	1.50 per cent Ni 0.75 per cent Cr	To secure resistance to scaling at high temperatures.
Forming Dies	1.00 per cent Ni 0.40 per cent Cr	To secure strength and toughness.

Power is usually at a minimum, and tool endurance at a maximum when finishing cuts are taken.

In the writer's work (35) it was observed that for a given depth of cut, the number of cross-lines on the steel land after a chip had been removed varied with the degree of tool sharpness. With a keen cutting edge, there were more slips per inch which gave a better finish than with a dulled edge. Fig. 20 shows the chip slippage lines per inch plotted over the degree of tool sharpness as abscissa. The 10, 20, and 30-degree front-rake, end-cutting tools were used. The width of cut was ½ inch and the depths of cut 0.006 and 0.031 inches. The highest curve shows that for a 30-degree front-rake tool taking a depth of cut of 0.006 inch there are 40 slips per inch for the honed edge, which is reduced to 26 slips per inch for the dullest edge. There appears to be little difference in slippage for the first three conditions of tool sharpness; also the slippage variation is reduced for the heavier cuts, as shown by the dashed lines. It is also seen that the cut is smoothest for the greatest rake angles.

These slippage lines may be due to the slippage of the metal over the tool in the formation of a chip or they may be a function of chatter. There was no obvious indication of chatter.

When cutting cast iron for a given heavy depth of cut it

was observed that there was no appreciable difference in surface condition after the removal of the chip by tools having various rake angles and degrees of tool sharpness. There is a very noticeable chip slippage for the 0.031-inch depth of cut in cast iron, but the surface is so smooth that the number of slips per inch cannot be seen distinctly nor can they be accurately counted. As with steel, it appeared in every case that the initial degree of tool sharpness was changed by the first cut of 3 feet, but that this new condition was then maintained for the remainder of the test.

It was further observed that in all cases of steel, the material seemed to be torn rather than cut by the tool cutting edge. In every case, there appeared to be a nose built up from the cut material which protected the cutting edge. For the very thin chips, less than 0.003 inch, this false cutting edge was not observed and the surface of the bottom of the chip as well as that left on the material appeared burnished or smooth.

In Fig. 3, is shown the unit force on a tool as a function of its front-rake angle when cutting brass. The lines shown dashed are drawn through those points at which chatter was obvious. This was the first indication that the author had of a reduced force when chatter occured but it was confirmed many times later in cutting brass. The finish was obviously rougher. Dempster Smith in commenting on this point stated that he has observed that the tool life was extended when chatter occured in cutting steel and that the results were so uniform that they could be duplicated at will.

Vanick and Wickenden (36) state that "for any particular steel and heat-treatment thereof, together with a specific tool, feed, and depth of cut, there is a critical speed at which invariably a rough finish will be produced. At speeds greater or less than this critical range of speed, the finish produced is smooth and satisfactory. The speeds or cuts suitable for obtaining fine finishes are dependent upon the strength and hardness of the individual steels, apparently irrespective of composition. For efficient cutting speeds, the limit hardness should be under 200 Brinell. The conditions which leave a rough surface may be changed to leave a smooth finish by (1) either lowering or preferably increasing the cutting speed until it is outsite of the critical range; (2) changing the depth of cut or feed; (3) pro-

viding a new tool cutting angle; or (4) changing the hardness of the steel being cut."

They report further that "the critical range of speed giving a rough finish is apparently lower the higher the Brinell hardness of the steel. Thus, steel No. 2315, which at a Brinell hardness of 166, gave a critical range of 69 to 95 feet per minute and when annealed to give a Brinell hardness of 155, showed a critical range of 100 to 140 feet per minute. The speeds and cuts suitable for obtaining fine finishes are dependent upon the strength and hardness of the individual steels, irrespective of composition. For efficient cutting speeds the limiting hardness is under 220 Brinell and preferably under 200 Brinell. These are hardness values which are readily obtained by normalizing or annealing."

"The critical range of cutting speed for rough finish is also reduced by increasing the sharpness of the tool angle. Sharper tool angles such as would be obtained by increasing the cutting angle from 68 to 60 degrees, reduce the high speed necessary for a good finish approximately 30 per cent. Thus, S.A.E. steel 2512 having a Brinell hardness of 150 yielded the following typical result:

Cutting Angle Degrees	Feed Inches	Cut Inches	FEET PER MINUTE Smooth Finish at High Speed Min.	Max.	Low Speed Min.	Max.	Poor Finish Speed Min.	Max.
68	0.015	0.030	145	285*	0	75	75	145
60	0.015	0.030	90	220*	0	45	45	90

*Maximum obtained at 108 and 85 revolutions per minute, respectively."

Force on Tool and Durability Vary With Speed for Thin Chips

The speed-durability curve for cutting steel or cast iron has been shown above to follow the equation VT^n equals a constant, that is, the durability of the tool decreases continuously as the speed increases. It has been shown by E. G. Herbert (30) that for light cuts the durability increases with the speed up to a maximum, declines, and increases to a second maximum, and finally falls off at higher speeds. These experiments were made on the Herbert Tool-Steel testing machine where the work was in the form of a tube which rotated against the tool held in a special vise. To confirm Herbert's results, Dempster Smith (19) constructed a dynamometer which was fitted to the turret of a lathe. With extremely light cuts, it was found that the force for

a given cut would not remain quite constant at all speeds, but by adopting a percentage increase of the initial force, this small variation would not appreciably affect the standard for durability. Fig. 21 shows the relation between the cutting speed in feet per minute and the percentage increase of the initial vertical force on the tool of 5, 10, and 15 respectively. With the 15 per cent increase, the cutting edge was seriously injured while with a

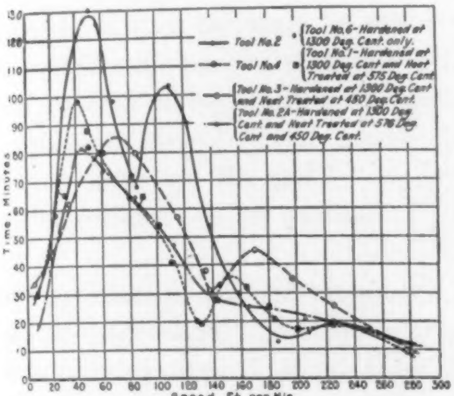

Fig. 22—Speed-Durability Curves on Bar Lathe Cutting Medium Steel, Depth of Cut 0.0625 In. and Feed 0.0013 In. with Variously Heat-Treated Tools. (Israel Hey.)

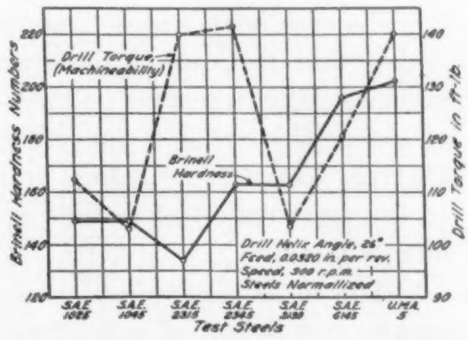

Fig. 23—Comparison of Machinability, Drill Torque and Brinell Hardness of Seven Grades of Steel. (Benedict and Hershey.)

5 per cent increase, the cutting edge was not impaired. Fig. 22 shows the speed-durability curves obtained by Israel Hey on the lathe for variously heat treated tools when cutting steel with a cut 0.0625-inch deep and 0.0013-inch feed. It was found that the significant fluctuations occured when tools of carbon steel, high speed steel, and Stellite were used. Similar curves were obtained by Smith for a given tool for various traverses. It was shown that if the point of maximum durability be compared, that for the smallest traverse (0.0013-inch) occurs at 40 feet per minute; that for the next larger traverse (0.01 inch) at about 5 feet per minute; while low enough speeds could not be obtained to give the corresponding maximum points for the larger traverses. He thus concludes that the durability curves move bodily toward the lower speeds as the traverse is increased. This is due to the increase in temperatures of the tool and shavings brought about by the increase in heat generated in removing the bigger dimensioned cuts. The hardness values for the tool and metal operated upon are much the same at the low speeds for the

heavier cuts as those associated with the higher speeds and finer cuts. The movement of a curve towards the left of the figure indicates that, when the traverse is increased to that of an ordinary roughing cut and taken at workshop speeds, the peaks will be eliminated completely and the regular durability-speed curves commonly associated with roughing cuts will be obtained.

Drilling as a Means of Measuring Machinability

The ease with which a sample piece of material may be drilled makes this method of determining the relative machinability of metals highly desirable. Types of machinability testers making use of the drill have been reported by Bauer, Keep, Leyde, Reininger, Kurrin, Kessner, Benedict, and others. They all use some factor of the penetration of a drill as an indication of the machinability of the metal.

The author has developed a dynamometer for measuring the torque and thrust of a drill while it is cutting. The values of the torque in foot-pounds developed by a drill 1 inch in diameter having a helix angle of 28 degrees, a clearance angle of 6 degrees, as ground on a Blau drill grinder, when cutting at 94 revolutions per minute and taking a feed of 0.006 inches per revolution, are shown in Figs. 1 and 8, curve A. These drilling tests were taken on the same bars that were tested in previous experiments on the planer. It is gratifying to note that the torque curve follows very closely curve B, the force in pounds per 0.001 square inch of chip area on the end-cutting tool having 15-degree front-rake angle.

Benedict maintains that the torque on a drill is an accurate measure of machinability. Fig. 23 shows the results of his drill torque indicating machinability and the hardness of seven grades of steel. He points out that with the exception of the chromium steel, the machinability of the steels tested, as indicated by the drill torque, appears to be unrelated to the Brinell hardness. He states further that both the torque and hardness for the chromium steel are high, and although this steel is difficult to drill at 0.032 inches per revolution (speed, 330 revolutions per minute), it is machined more readily than medium carbon-nickel steel, S.A.E. 2345, which has a Brinell hardness 19.3 per cent lower. "From the shop standpoint, machinability and hardness commonly are con-

sidered as synonymous terms. A 'soft' metal is assumed to be 'easy' to machine with a cutting tool, and vice versa. With the development of alloy steels and special foundry mixtures, however, the accepted relationship between hardness and machinability has ceased to be tenable. In fact, there is reason for believing that machinability may be dependent upon factors other than hardness as expressed by any of the conventional methods. This opinion, which has been becoming general of late, was confirmed in the case of a few steels by the test primarily organized

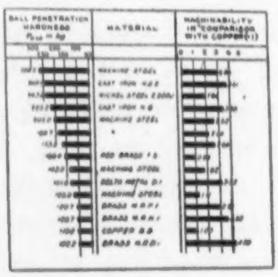

Fig. 24 — Ball-Penetration Hardness (Martens-Heyn Units) and Machinability of Various Metals and Alloys Based on Copper as Unity.

to determine the effect of helix angle on the torque and thrust of the drill. As the torque on the drill is an accurate measure of machinability, the data obtained in this test are definite though limited contributions to this subject.'' See Fig. 23.

Quoting from a paper (2) by Dr. Kessner, he states ''Hardness has been defined as the resistance which a body offers to the penetration by another, harder body. Plasticity is the ability of a body to undergo dislocation of its smallest structural particles, as a consequence of the application of external forces, at ordinary temperatures, without disturbance of their coherence. The resistance which a material offers to penetration by a cutting tool is due to its hardness and plasticity; the 'machinability' of the material depends upon the combined effect of these two characteristics.

''For determining the resistance to penetration by cutting tools, the author devised a drilling testing machine. In this, a numerical value for machinability is established by using a drill as a cutting tool and measuring the drilling depth obtained by

100 revolutions of the tool. The test is based upon the consideration that for a definite load the depth of drilling obtained by a definite number of revolutions may be greater in proportion to the better machining qualities of the material under investigation.

"The recording pencil automatically draws a diagram the ordinates of which are the number of revolutions of the drill and the abscissas are drilling-depth values. If the material under investigation is homogeneous and its thermal conditions remain constant, the autographic record will be a straight line. The angle infinity which this line forms with the horizontal is a measure of the machinability of the material under test."

"Since, however, the measurement of this angle may introduce an error, the actual depth of the hole drilled by 100 revolutions can be taken as measure of this property (assuming that all external conditions such as load on drill, revolutions, diameter of drill, cutting edges, and all angles, remain constant)."

Since drilling does not yield absolute values but only comparative ones, Kessner selected rolled and annealed electrolytic copper as giving a machinability of unity. The machinability of another metal is then compared with copper. Results of some tests made jointly with Dr. Heyn are shown in Fig. 24.

Cutting Speed Expressed as a Function of Physical Properties

Taylor developed the following empirical formula which was a partial guide to the cutting speed of steel of good quality, when the physical properties of the forging were known.

$$V = \frac{125\left(1 - \frac{215}{(15 + E)^2}\right)}{\sqrt{\frac{S}{10,000} - 3} - 0.9}$$

in which V equals the cutting speed required to cause his standard $\frac{7}{8}$ inch tool when taking a cut $\frac{3}{16}$ inch depth and $\frac{1}{16}$ inch feed to fail in 20 minutes; S equals the tensile strength of the material in pounds per square inch; and E equals percentage of elongation of specimen 2 inches by $\frac{1}{2}$ inch.

French and Digges (31) checked Taylor's equation on a large variety of steels having tensile strengths from 80,000 to 195,000 pounds per square inch, determining experimentally the speed to

cause their tool to fail in 20 minutes and comparing it with the computed speed. Out of thirty-five experimental points plotted, only nine points differed by more than 20 per cent plus or minus from the computed value. They agree with Taylor that this formula is characterized as only a partial guide which does not, for either very hard or very soft steels, give values uniformly

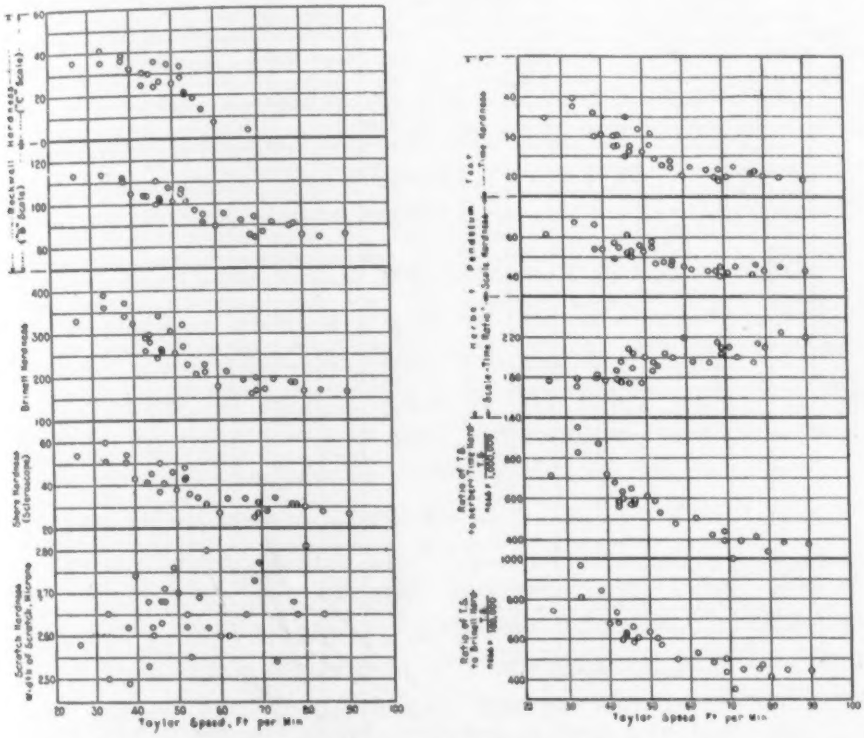

Fig. 25—Cutting Speed in Relation to Hardness of Steels Cut. Cutting Speeds Used are for Their Standard Tool When Dry Turning at $\frac{3}{16}$-In. Depth and a Feed of 0.028 In. Per Revolution. (French and Digges.)

close to the experimental observations. They report further that the "cutting speed is in no way even generally related to the energy required to break the steel in tension, as represented by the area under the stress-strain curves."

A very complete analysis has been made by French and Digges of comparisons between the Taylor Cutting Speeds and the mechanical properties of the steels cut. Their results are reproduced in Figs. 25 and 26. The following is quoted "as shown (in Fig. 25) none of the hardness tests is a quantitative criterion of the cutting speed but some give a better general indication than others. The scratch test in its present form appears to give ab-

solutely no indication of the cutting speed and shows the widest scatter of points, but this is undoubtedly due in part to the susceptibility of the method to errors in measurement.

"There does not seem to be much choice between the Brinell, Rockwell B scale, scleroscope, or Herbert time hardness from the

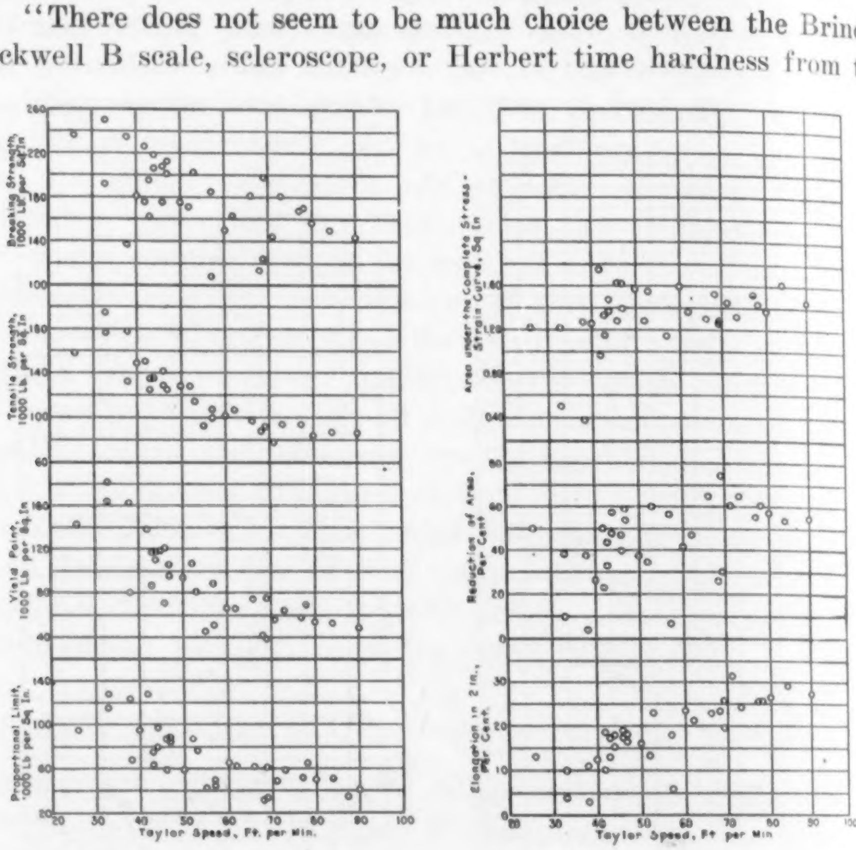

Fig. 26—Cutting Speed in Relation to Tensile Properties of Steels Cut. Cutting Speeds Used are for Their Standard Tool When Dry Turning at $\frac{3}{16}$-In. Depth and a Feed of 0.028 In. Per Revolution. (French and Digges.)

standpoint of a correlation with cutting speed, but certain other factors give to the Brinell test the most favorable rating. The two separate Rockwell scales required for steels varying so widely in properties as those cut in the reported lathe tests is a decided disadvantage. The scleroscope must be used with considerable care to secure consistent results, and the Herbert hardness tester is primarily a laboratory instrument whose readings depend largely upon the manipulative technique. Because of these features the Brinell test is at present considered the most useful of the group in giving a qualitative, but by no means a quantitative, indication of the cutting speed.

"Correlation of cutting speed with tension tests is given in

Fig. 26. In general, the cutting speed for a fixed tool life increases with decrease in tensile strength, proportional limit, yield point, and breaking strength and increase in elongation and reduction of area, but on the whole there is a wide scatter of points for each of these factors. The best general indication of the cutting speed is given by the tensile strength. Likewise, there is a smaller scatter in points representing elongations than in those representing the reduction of area, but the authors do not believe that these factors will ever be generally useful in the development of an accurate criterion of the cutting speed as they are too greatly influenced by variables which do not materially affect the cutting properties. The same may, of course, be said of the proportional limit and yield point."

Hardness as an Indication of Machinability

It has been pointed out above that in the author's work, the force on a standardized planer tool varies with the Brinell hardness numbers for carbon steels in one group and alloy steels in another, but that for cast iron, the force is constant over a wide range of Brinell numbers. See Fig. 14. It was seen in Figs. 15 and 16 that no such relations with the scleroscope and Rockwell numbers are indicated.

Klopstock shows Brinell hardness curves and chip-pressure curves for seven materials, including Kurrin's drilling test. He states that "it appears that the intersecting points of the hardness curves and chip-pressure curves will be found near two approximately parallel straight lines; one located considerably below the other. The upper line connects the intersecting point of curves relating to materials forming continuous chips such as steel, wrought iron, copper, etc., while the lower line connects the intersecting points of curves relating to materials such as cast iron and brass." "These observations permit the determination of chip pressure and, therefore, power requirements in the turning and planing of materials of which the Brinell hardness characteristics are known."

In a talk before the Lehigh Valley Chapter of the Society, A. H. d'Arcambal stated that in order to insure the use of good material, steel should be purchased by specifications rather than by brand. Specifications, in the case of the Pratt and Whitney Company, include not only chemical, physical, and metallurgical

properties, but also hardness limits which place the material within the range of commercial machinability. Further, he stated that limits of machinability are set in the Brinell scale and all incoming material is checked on hydraulic type Brinell machines.

The International Nickel Company (29A) state that by using nickel, it is possible to develop the full hardness of the matrix of the iron without the formation of carbide hard spots and attendant machining difficulty. Properly made nickel-bearing castings will, therefore, machine as readily at 250 Brinell as ordinary iron castings at 200 Brinell.

It seems to be generally accepted that a Brinell hardness of 200 is the upper limit for a commercial machining. This may be extended, however, by some to as high as 250 Brinell.

In the author's experience, gray iron sand castings having a Brinell of 160 to 180 frequently machined with difficulty (short tool life). This job was later transferred to a permanent mold machine made by the Holley Carburetor Company and it was found that the Brinell number was increased to a range of 180 to 200, although the machinability was much improved, due probably to the lack of the thin chilled surface.

French and Digges' results, Fig. 25, show a general relation between Brinell hardness numbers, ratio of tensile strength to Herbert time-hardness multiplied by tensile strength divided by 1,000,000, and the ratio of tensile strength to Brinell hardness multiplied by tensile strength divided by 100,000, and the Taylor-Speed in feet per minute. By Taylor-Speed is meant that speed which under standardized conditions causes the tool to fail in 20 minutes.

French states further that there is no reason why any one of the factors determined in the customary hardness or tension tests should be a qualitative criterion of the cutting speed when considering different steels. Roughing lathe tools of high speed steel fail due to the continued rubbing or wearing action of the chips passing over the tool. This finally results in a sudden spalling of the nose. He states further that hardness as customarily determined is not a criterion of wear and since wear causes the tool to fail, hardness would not be expected to give a qualitative tool-life (or cutting speed). Apart from this, however, he continues, the tools and chips are both at high temperatures in rough turning and it is known that the performance and properties of metals

under such conditions are not indicated by, nor necessarily related to, tests at atmospheric temperatures.

Influence of Cold Working and Temperature Rise

The following is taken from a letter to the author from E. G. Herbert of Manchester, England: "I think it is quite well established that there is no direct relationship between the hardness of metals and their resistance to cutting, and it has been my endeavor in 'The Pendulum' and elsewhere to show why such a relationship cannot exist. The principal reasons are, according to my experience, two:

"(1) When a metal is cut it is work-hardened in the process of cutting, and its resistance to cutting depends far more on its work-hardening properties, that is on the hardness induced in it by the tool, than on its original hardness. As a familiar example, manganese steel is shown by the Brinell test to be soft. This is confirmed by the pendulum time test which gives its hardness 24, the hardness of ordinary mild steel being 20. But manganese steel cannot be cut, and the reason is immediately made apparent by the pendulum 'work-hardening test' which gives its original scale hardness 14 and its scale hardness after being rolled with the pendulum ball 80 to 90, i.e., equal to the hardness of hardened tool steel. All other metals are similarly hardened by cutting tools, but in very different degrees, and their resistance to cutting must therefore depend on their 'work-hardening capacity.'

"(2) Metals are heated in cutting, and their resistance to cutting must therefore depend on their properties when in a heated state—not cold. The hardness of steels and other metals does not generally change much within the ordinary range of cutting temperatures, but their work-hardening properties do change in a remarkable manner, almost disappearing in many cases at temperatures (in mild steel) between 100 and 150 degrees Cent. Any study of machinability which fails to take these facts into account must, in my opinion, lead to negative results."

Fig. 27 shows a drawing of a photomicrograph (X10) by Herbert (30) showing the values of the time test made with the pendulum hardness tester. It is seen that the hardness of the body or unworked portion averages about 22, while the chip which has been torn, sheared, and bent averages about 33, and the false cutting edge 44.8.

Fig. 28 shows a similar set of hardness readings for brass. The distortion of the chips is small and the work-hardening less. Herbert has shown that the work-hardening capacity of a metal varies with the temperature, having alternately high and low values as the temperature is increased. Herbert has also shown that, under standardized conditions, the temperature between the

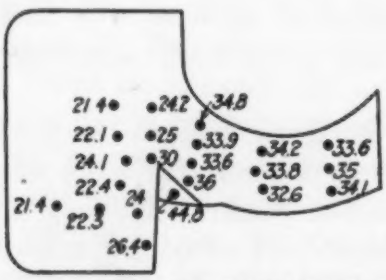

Fig. 27—Hardness Induced by Tool in Mild Steel (5 x). Showing Wedge Built Up on Cutting Edge of Tool. Depth of Cut is 0.037 In., Speed 65 Ft. Per Min. (E. G. Herbert.)

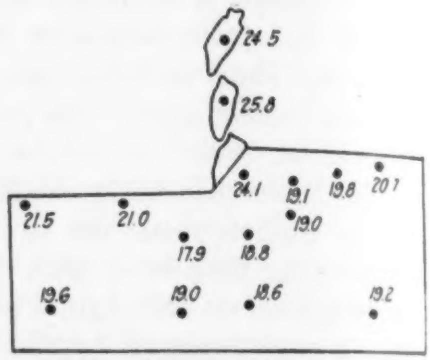

Fig. 28—Hardness Induced by Tool in Brass (5 x). Showing the Slight Distortion of Structure and the Small Increase in Work-Hardness of Brittle Chips. (E. G Herbert.)

tool and work (measured thermo-electrically) varies with the cutting speed and at certain speed ranges the temperature falls below the normal curve. At these low temperature ranges, the finish of the work is best. Metal cut within this range is only slightly hardened by the tool with the following results:

1. The metal cuts freely, leaving a smooth finish.
2. Less heat is generated.
3. A flowing helical chip is produced.
4. A bright Whitaker ring is formed.

Herbert has shown that the depression of the work-hardening temperature curve coincides with that of the temperature-cutting speed curve.

The practical application of the relation between finish, speed, chip size and shape, and tool, as determined by Vanick and Wickenden, has been referred to above under the heading of *Finish*.

The author believes that much is to be gained by a continuation of the work on work hardening determination as undertaken by Mr. Herbert, as this appears to be a new and novel method of gaining an understanding of the relation between temperature, speed, and chip size and deformation.

Cutting Fluids as an Influence on Machinability

Time does not permit a review of the literature on the subject of cutting fluids. A few remarks relative to the influence of a cutting fluid on roughing or finishing cuts, however, seems indicated.

French and Digges (31) recently showed that the best that could be expected by way of increased cutting speed for a given tool life of high speed steel tools was from 5 to 15 per cent when cutting steel. Also, it was shown that soda water gave best results. An emulsion and paraffin oil was next, in order of value over cutting dry. These values agree well with Taylor's when cutting steel. Taylor also found that 15 per cent was about the best that could be expected in increased speed when cutting cast iron using water. It appears that in rough turning the increased tool life is due more to the cooling action than to the lubricating value of the coolant. Herbert (30) found in rough turning that the lowest working temperatures, under otherwise comparable conditions, were obtained with water, intermediate temperatures with oil, and the highest temperatures when cutting dry.

In taking finishing cuts, factors other than cooling are presented. There appears to be little of a scientific nature available in our literature relative to the action of cutting fluids. Practice appears to be built upon shop experience so that when conditions are changed, the solution is brought about by the cut and try method.

With reference to finishing cuts, Smith (19) states "the opinion is commonly held that at the higher speeds the durability of a tool is much greater when a cooling medium is used than without. Contrary to this belief, however, it was found that beyond about 130 feet per minute, the tool, when cooled by a cutting compound of lard, oil, and water, broke down after a comparatively short run and could not be made to attain the durability of the tool when operating dry. Water alone was substituted, but the results obtained were even worse."

An investigation to make a beginning on the general problem of correlating performance characteristics of cutting liquids with their physical and chemical properties, with a view to more efficient selection of cutting fluids in machine shop practice has recently been authorized at the Bureau of Standards. This work is being

sponsored by the Special Research Committee on the Cutting and Forming of Metals of the American Society of Mechanical Engineers.

Summary and Conclusions

As stated at the beginning, the object of this paper is to outline the various methods which are being used to designate the machinability of metals and to present substantiating data. The work of many authors has been referred to and their conclusions on certain phases of machinability have been presented. These works involve different methods and standards which in many instances make comparisons difficult. Ways for designating the relative machinability of various metals have been presented. Because of the large field covered, it is impracticable to summarize and state the conclusions. Some methods show consistent relations between the factor of machinability and the physical properties of the materials which offer general guidance in practical work.

It would be well if the various methods of testing machinability could be compared by direct data from the test bars so as to find if the torque or the feed in inches per 100 revolutions of the drill; or the force, power, tool endurance, or Taylor-Speed, etc., in straight line cutting or turning; the energy absorbed by a milling cutter, etc., have anything in common.

Further, for determining the machinability of a metal under variable conditions, it appears that continued study of the properties of the metals at elevated temperatures as caused by the heat generated in cutting, the work-hardening by the tool of the material being cut, as well as further light on the subject of chip formation, will lead directly to a more thorough understanding of the principles underlying metal cutting.

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30. "Work Hardening Properties of Metals."—E. G. Herbert, (a) Shows that cold working increases hardness, (b) that a cutting tool deforms and therefore hardens the steel, (c) that metal cutting heats the metal and that the induced hardness is a function of temperature. *Transactions*, American Society of Mechanical Engineers, 1926, 43 pages, 37 figs., p. 705.
31. "Rough Turning with Particular Reference to the Steel Cut."—H. J. French and T. G. Digges, *Transactions*, American Society of Mechanical Engineers, 1926, 69 pages, 22 figs., p. 533.
32. "On Cast Iron."—Dr. R. Hohage, Essen. Abstract in TRANSACTIONS, American Society for Steel Treating, November, 1926, p. 821.
33. "Machining Magnesium Alloys," *American Machinist*, December 30, 1926, p. 1076.
34. "Hardness and Machinability of Grey Iron Castings."—E. J. Lowry, S. A. E. Paper at Detroit, January 25-28, 1927.
35. "A Research in the Elements of Metal Cutting."—O. W. Boston, *Transactions*, American Society of Mechanical Engineers, 1926, 92 pages, 83 figs., p. 749 (see Table I).
36. "Smooth Finish Machining of Low Carbon Plain and Alloy Steels."—J. S. Vanick and T. H. Wickenden, TRANSACTIONS, American Society for Steel Treating, April, 1927, p. 551.
37. "Mechanical and Machining Properties of an Annealed Cast Iron."—G. C. Priester and F. J. Curran, TRANSACTIONS, American Society for Steel Treating, May, 1927, p. 741.
38. "Comparison of the Alloying Elements Chromium, Nickel, Molybdenum, and Vanadium in Structural Steels."—H. J. French, TRANSACTIONS, American Society for Steel Treating, June, 1927, p. 859.
39. "Effect of Nickel on Machinability of Cast Iron."—D. M. Houston, *American Machinist*, June 9, 1927, p. 961.

DISCUSSION

Written Discussion: By A. L. Boegehold, General Motors Research Laboratories.

It might be appropriate as a discussion of Professor Boston's excellent paper, to describe an apparatus for studying machinability of metals devised after studying apparatus referred to in his paper and discussing some of the results obtained with it with reference to data he has cited.

The apparatus consists of a sturdy, direct, motor driven shaper with a

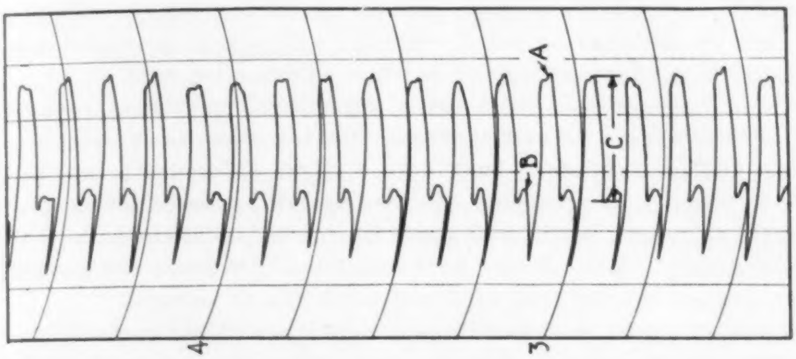

Fig. 1—Maximum power consumed in cutting is indicated by peak A. Power consumed by the quick return of the ram is indicated by small peak B. The distance marked C, gives the maximum power consumed in cutting.

sensitive recording wattmeter hooked up to the motor. The tool used is round nosed ground to fit templates insuring shape of nose and a side rake of 7½ degrees, front rake of 7½ degrees and a clearance angle of 1 degree

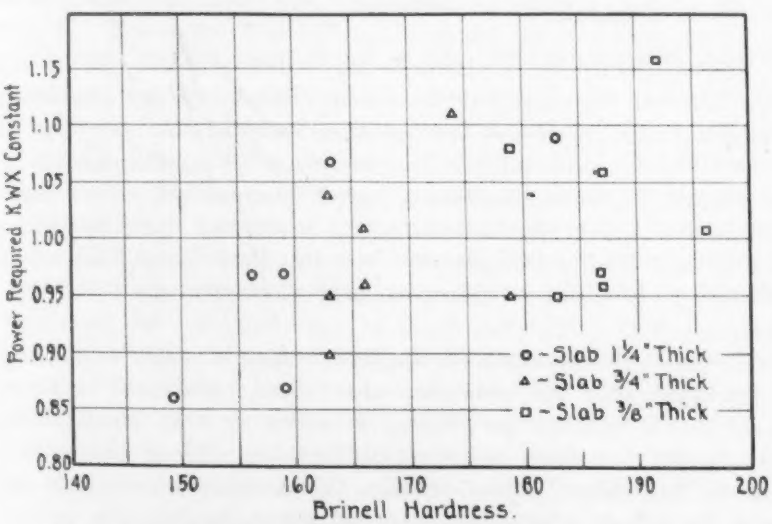

Fig. 2—Results of machinability tests on slabs of 3 thicknesses from 7 heats of fly-wheel iron plotted against Brinell hardness.

15 minutes. The material tested with this apparatus has so far been entirely cast iron. The test specimens are made in the shape of slabs 1¼ x 6 x 14 inches, ¾ x 6 x 14 inches, and ⅜ x 6 x 14 inches to study the effect of section size on hardness and machinability and the effect of varying cupola charges on hardness and machinability.

The slab is clamped firmly in the standard vice and with a cutting speed of 26 feet per minute, the tool removes successive strips of metal ⅛ inches deep by .027 inches wide. The type of curve obtained is shown in Figure I.

It is agreed with Mr. Boston that power consumed in itself is of relatively little interest for a given rate of machining, but we believe that it also indicates whether or not a material will permit increased machining speeds and thus effect savings by increased production rate.

It can be seen that with wide variations, machining requires more power with increased Brinell hardness. On the other hand, specimens varying from 156 to 196 Brinell have only a slight difference in machinability. This is in line with a great deal of existing data, some of which Mr. Boston has given, showing that Brinell hardness cannot be taken as an indication of machinability. The relation between Brinell hardness and machinability must be worked out for each kind and condition of material.

The variation in machinability of cast irons of the same hardness and vice versa, the divergence of hardness in irons of equal machinability can only be explained by the constant rearrangement and variation of the multitude of influences which operate to determine the final heterogeneous structure of cast iron. It is the problem of the metallurgist to trace these causes through the cupola operation, the raw material proportions and quality, and the physical environment of the casting to determine the set of conditions that will give the best machinability compatible with strength and durability requirements.

Written Discussion: By Carl G. Barth, New Haven, Conn.

The only way of measuring the relative machinability of various metals that appeals to the writer, is the one mentioned as No. 3 in Prof. Boston's paper, modified to read only: "The ability of a standardized tool to cut various metals in terms of cutting speed", which of course also implies that a standard depth of cut and feed is used, and that the cutting speed is that which makes the tool give out in a standard time. This was Taylor's way, though neither he nor I ever used the term machinability in our practice.

However, as the pressure on the tool is also a factor in cutting, it too should be taken into account when theoretical refinement is desired; but as the range of variation in cutting pressures is very small as compared with the range of cutting speeds, and that the cost of power cuts but a small figure in practical metal cutting, the pressure on the tool is too unimportant for purely every day practical purposes.

However, from a purely scientific point of view the method of measuring machinability in terms of power consumption, as suggested under No. 2, which is of course simply a combination of methods No. 1 and No. 3, seems very attractive. Hence the following exposition may be of some interest.

The tangential pressure on a lathe roughing tool cutting any metal appears to be more or less closely expressed by an empirical formula of the form

$$1. \quad P = C_p \times F^n \times D^m$$

in which
P = Pressure
D = Depth of cut
F = Feed of cut per revolution
C_p, n and m what may be called the pressure constants for any particular material.
Similarly the cutting speed at which the tool will give out in a certain standard time may be expressed by the formula

$$2. \quad V = \frac{C_v}{F^p \times D^q \times T^u}$$

in which
C_v, p, q and n may be called the speed constants of the material.
Multiplying [1] and [2] together and dividing by 33000 then gives the net horsepower consumed by the cut, namely

$$3. \quad HP = \frac{C_p \times C_v}{33000} \times \frac{F^{n-p} \times D^{m-q}}{T^u}$$

But not only does the power depend on the above referred constants of the material, which may now collectively be called the machinability constants of a particular material, but also on the values of F, D and T adopted as standards—in such a manner that the ratio of the two power consumptions for any two materials obtained by the use of certain values of F, D and T and adopted as standards, would be different from the ratios of similar power consumptions obtained by the adoption of other values of F, D and T as standards. Even the size of tool adopted as standard modifies the values of the machinability constants themselves. In other words, there is no way of getting an absolute comparability measure for the machinability of various materials by means of power consumption, any more than apparently by any other method so far proposed.

In fact, in my opinion present day investigators in the field of metal cutting are getting too ambitious along impractical lines, and neglecting their opportunities along truly practical lines. Thus also, the matter of economy in power consumption in practical metal cutting is of such minor consideration from the point of view of total cost, which is the only thing that really counts, that elaborate and costly experiments to ascertain cutting pressures as of primary importance represent, in my judgement, just so much waste. For this reason it is gratifying to read Prof. Boston's statement that manufacturers lack interest in methods involving economy of power so far as metal cutting is concerned. Taylor himself took pains to warn future experimentors not to waste time and money on pressure experiments to the sacrifice of obtaining facts of more practical value for the same efforts.

In this connection I cannot refrain from criticising Prof. Boston for quoting those immensely elaborate impractical cutting speed formulae from Taylor's "On the Art of Cutting Metals", the general one of which is even reproduced somewhat incorrectly. In correspondence of more than

a year ago I referred Prof. Boston to certain publications by me that gave the facts about those formulae and their predecessors of real practical value, as well as much other material dealing with the art of cutting metals.

Written Discussion: By President Ralph Earle of the Worcester Polytechnic Institute.

At the time when the term "machinability" was most needed in our industry, it was not used or incorporated into specifications for materials. The sad lack of this quality in certain metals of the same tensile strength to the happy presence of it in the same metals in the manufacture of munitions during our World War was not only disturbing and annoying but decidedly dangerous in the consequent uncertainty as to whether this or that piece of important work might be completed on time.

Therefore, I am sure this research by Mr. Boston will benefit industry exceedingly, for it ought to be the means of insuring freedom from most embarrassing situations in the machine work required upon metals.

To illustrate some of the incidents that developed, because of a lack of a uniform machinability in metals of similar characteristics, one or two of the experiences of the World War may be cited.

The air flasks for automobile torpedoes for the Navy are all of the best steel obtainable, and must, in a 21 inch diameter cylinder, be such that thinness of wall be at a minimum in order that lightness may be kept, and yet the safe internal pressure may be upwards of 2600 to 3200 pounds per square inch. Such cylinders were made by forging billets of steel, or by drawing of the steel into tubes. The latter procedure gave uniformly the best machinability, while by the former procedure some cylinders could not be machined into air flasks because no tool could work them and yet others machined quite easily. There was a great difference thus in the time required to produce the air flask, which, coupled with the uncertainty as to the time, introduced into torpedo manufacture an embarrassing situation. If machinability had been specified, there would have resulted none of this anxiety as to whether or not the finished article would be ready on time.

A conference called early in the World War with the object of adopting uniform speed in cutting the surfaces of steel tubes for guns showed the widest variance existing in width, depth, and speed of cutting. This condition was one undoubtedly due to the varying machinability of metals. As the machine work and assembly in the case of producing the largest caliber gun with best practice amounts to about fourteen months any slowing of this machining in war time could hardly be faced with equanimity. Hence cutting depths and speeds were specified, a procedure that greatly contributed to the resultant completion during the war for the Navy of some thousands of guns.

These are but two of the many practical applications and uses to which uniform machinability of metals of similar materials apply, as when a standard in metals as to machinability as certain and as dependable as the proportions of substances therein and as the strength and hardness can be

demanded and obtained, a much greater assurance as to the time of completion of articles can be felt by the manufacturer and by the user. The author of this paper has laid out the ways and means whereby this quality may be measured, and thus may be specified for material, and these being all the result of very careful research are reliable, and his research should have its reward in the general improvement of metal cutting in industry.

Written Discussion: By Bruce W. Benedict—University of Illinois, Urbana, Ill.

Professor Boston has performed a fine service in presenting in one paper the various methods thus far developed for determining the machinability of metals. His effort may be considered as a start in the large task of bringing the word "machinability" as applied to the tooling of metals, within definite boundaries, and of developing an adequate technique for expressing machinability in exact terms. The American Society of Steel Treating would seem to be the logical agency for continuing this important work.

The term "machinability", as I understand it, deals with the cutting properties of metals rather than with the finish after tooling. Machinability may be considered as a measure of the internal resistance of the crystalline structure of the metal to rupture by the cutting tool. In the process of removing the chip, force is applied and work is performed, resulting in the generation of heat and reduction in the volume of metal. It should theoretically be possible to determine machinability by measuring (in removing a unit quantity of metal) (a) the heat generated, (b) the force and the power required, (c) the time required, (d) the effect in the cutting edge of a standardized tool. Of these methods the simplest and most accurate appears to be the second, i.e., the measurement of machinability by determining the force required to cut a chip of a certain size at a predetermined rate by a standard cutting tool. In this method uniform cutting edges are easily produced and maintained, and the resulting forces are readily and closely measured (error less than 4 per cent) by simple apparatus. The only important variable in the apparatus is the shape and condition of the cutting edge. Experience shows that this variable may be controlled within practical operating limits by the use of regular shop equipment.

Apparatus to measure and record the force applied to the cutting tool may be designed in the form of dynamometers for engine lathes, milling machines, planers, shapers, and drilling machines. After some experimenting I have come to believe that the drilling machine is better adapted for measuring machinability than any of the machines mentioned. Power consumption at the point of a twist drill in drilling metals is produced largely by drill torque. Tests show that of the total power required at the drill point, torque accounts for nearly all of it (96 to 99.5 per cent of the total, depending upon the drilling rate) while friction resulting from thrust on the end of the drill accounts for the small remainder. Side friction is negligible in shallow holes. In no other machine tool is it possible to

measure as a single factor so large a percentage of the total power expended in cutting. Twist drills of uniform structure and hardness make it possible to maintain a standard cutting edge without difficulty. Uniformity of test results is a characteristic of this type of apparatus.

The object of this communication is not to express opinions about a topic of which so little is known but to pledge my cooperation in any movement which will increase the existing store of knowledge relating to it. Professor Boston's suggestion to compare the various methods of indicating machinability by tests using standard test bars is worthy of consideration and I would be glad to cooperate in the execution of such a plan.

Written Discussion: By Edward G. Herbert, Edward G. Herbert, Ltd., Manchester, England.

Professor Boston's paper, containing as it does a critical summary of the evidence produced by various workers, cannot fail to be of interest and value to all who are interested in the machinability of metals.

The most striking feature of Prof. Boston's original contribution to the enquiry is his division of the common metals into three distinct groups containing, A, cast iron and brass, B, straight carbon steels, and C, alloy steels.

The microscopic study of chip formation, on which I have been engaged for some time, affords clear justification for the placing of the group A metals in a class by themselves. The metals in this group are cut by shearing into fragments with little or no distortion of the metallic structure and without much hardening of the metal ahead of the tool or in the chip. All the metals in groups B and C are crushed and work-hardened ahead of the tool before separation of the chip takes place. The tool actually cuts metal whose hardness is much greater than that of the original stock, and this fact might be expected to differentiate these steels from the metals in group A in which such hardening does not take place.

There is scarcely less difficulty in justifying the separate classification of ordinary low carbon steels and *some* alloy steels, especially those containing a high percentage of chromium or manganese. In cutting one of the latter class I have recently obtained a chip whose hardness was equivalent to 700 Brinell, though the bar from which the chip was cut was quite soft. It is not difficult to understand why such a steel should be difficult to machine, whether machinability be measured by the force required to separate the chip or by destructive action on the tool. It is not difficult to understand why such steels should appear to class themselves apart from carbon steels of similar original hardness, whose chip hardness does not generally rise much above 300 Brinell. When however it is proposed to place all carbon steels in one group and all alloy steels in another, the question arises whether it is possible to draw a sharp dividing line between carbon and alloy steels, either as regards composition or machinability.

The evidence in my possession is not yet complete, but so far as it goes it seems to indicate that the steels in groups B and C can be placed in a series of ascending resistance to machining, this series corresponding gen-

erally with their work hardening capacity, and not corresponding at all closely with their original hardness.

ALVAN DAVIS: I have been trying in the last hour or so to prepare a few remarks, but, naturally, they are inadequate for such a complete and able paper as that of Professor Boston's. However, to pass up the opportunity to speak on it when you are deeply interested in the subject, would be worse.

In attempting to find the relation of the force, or the power, or the energy per unit of metal cut, in performing a machining operation, we have to do with an equation which manifestly involves a great many different factors. If we call the force the unknown thing, and speak of that as "X," then we will have "X" equated to a long term embodying many factors, which can, however, be collected into two groups. The first group would include those factors pertaining to the manner of the test, such as the form of tool, the width of cut, the depth of cut, the cutting speed, the lubricating quality of the cutting fluid that you use, the cooling effect or value of that cutting fluid, and finally, as Professor Boston has brought out, the rigidity of the machine, which affects vibration. I might say that it is known in practice that vibration can be used to accelerate production. This first group has been more or less sifted out, and we know pretty well about them through such work as that of Professor Boston and many others; his admirable paper throws light on many, if not all, of these factors.

We have in the second group factors depending on the nature of the material being cut. Numbering them, I would say first, hardness, as measured by elastic limit, either tension or compression; and if you haven't the elastic limit, then by the Brinell machine, or perhaps even the Vickers Pyramid number. Second, the ductility, as measured by elongation or reduction of area in the tensile test. Third, the rate of work-hardening of the metal under the temperature conditions obtaining during the test, (Mr. Herbert's contribution particularly). Fourth, the shearing strength of the material under working conditions prevailing during the test. And fifth, the coefficient of friction of the metal against the tool and against itself.

Unless all of these factors are taken into account, the results will be discordant and baffling. Failure to take into account one or more of these factors has been responsible for many failures, to get concordant results.

In this second group, numbers 1 and 2, hardness and ductility, have been pretty generally recognized, being very important factors, at least, in the power required, and they are not generally overlooked. Factor 3, the work hardening, has been brought out only quite recently. Factors four and five, (the shearing strength under the prevailing conditions and the coefficient of friction,) are not generally recognized, but I think they are important. I believe that it is due to its effect on shearing strength that the addition of a tenth of one per cent of sulphur to an ordinary low phosphorus and low sulphur open hearth machinery steel will increase its machinability to at least double what it was, and improve the finish at the same time, without notably changing its ordinary tensile test properties.

And similarly, in brass, the addition of rather a more significant proportion, 3 per cent, of lead will increase many times the possible machining rate and the finish. Finally we might add grain size. Certain it is that by heat treating relatively unmachinable steels, as by normalizing, very nasty machining problems have been mitigated in the automobile industry, and again without notably changing the tensile properties.

Time permits no more, though this comment is entirely inadequate to do justice to the very fine paper that Professor Boston has presented.

Author's Reply to Written Discussion:

The method of determining machinability of metals on a shaper as outlined by Mr. A. L. Boegehold of the General Motors Corporation is interesting and probably gives satisfactory comparative results. All wattmeter records on a shaper are roughly comparable only. The exact record obtained depends on the amount of dampening and even the speed of the chart, so that exact cutting forces or power will not be as accurate as on the author's planer dynamometer, as referred to in the paper. It appears that the value C shown on the chart is not wholly a function of the power required to remove the chip. C is greater than A minus B. A includes the power to drive the ram forward as well as cutting, while B is the power for reversing the ram and is not involved in A. C should therefore, in my opinion, equal A minus D, in which D is the idling load on the forward stroke.

Mr. Barth's exposition on "absolute comparability measure for the machinability of various materials by means of power consumption" is interesting and in content agrees with the opinions held by the author. It is for this reason that several curves, Figs. 3 to 7, incl., are included in the paper to show the influence of speed, chip size and shape, and tool shape for a given material. Also, it is for this reason that standardized conditions are called for. The lack of such standards in the mass of work which has been done makes direct comparisons impossible.

I believe that investigations along so called impractical lines are necessary before we can answer the question—what happens when metal is cut? Certainly impractical work of the right type is needed to explain and improve present practice.

The general formula for cutting speed for a twenty minute tool life expressed in terms of feed, depth of cut, and tool nose radius was referred to in view of the recent research work by French and Digges at the Bureau of Standards which checked the general formula for a given tool shape, but for a wide variety of steels.

G. W. Walker: I have a question I would like to ask Professor Boston with regard to machinability. We have had trouble occasionally with annealed steels in machining them. The particular steel I have reference to was a 6130. Now, if it is annealed so as to get a completely pearlitic structure, it machines all right, but if we get granular pearlite, it doesn't

(Continued on Page 154)

ON A NEW METHOD OF QUENCHING STEELS IN A HIGH TEMPERATURE BATH

By Kotaro Honda and Kanzi Tamaru

Abstract

The authors of this paper discuss the method of quenching steels in hot media so that they may obtain a troostitic or sorbitic structure directly, without tempering as is now done, after a steel is water or oil-quenched. By using a hot quenching media there is also little chance of quenching cracks being formed. The authors state that the structure of a steel quenched in a bath at about 930 *degrees Fahr.* (500 *degrees Cent.*) *is sorbitic. The mechanical properties are not inferior to those of a steel quenched in water and then tempered.*

Introduction

A TEMPERED structure of steels, such as troostite or sorbite, is usually obtained by quenching steels in water or oil followed by tempering at a suitable temperature. This heat treatement of steels is not only troublesome, but is also very dangerous, because cracks migh be produced by the quenching. If the cracks be too small, they might remain undetected in the steels, and after a certain period of use, the fatigue of the material might start from one of them and may become a cause of the failure of the specimen. Hence it is desirable to have some other method for obtaining the troostitic or sorbitic structure without fear of the formation of cracks.

According to the theory of quenching put forward by one of the present writers[1], these structures can be expected to be directly obtainable by a soft quenching in comparison with the ordinary one. This soft quenching may be effected by quenching the specimen in a hot bath of suitable temperature. A few such investiga-

[1]Honda, Science Reports, Tohoku Imperial University, Sendai, Japan, VIII, p. 181, 1919.

A paper presented before the ninth annual convention of the society held in Detroit, September 19 to 23, 1927. Of the authors, Dr. Kotaro Honda is honorary member of the Society and professor of metallurgy, Tohoku Imperial University, Sendai, Japan, and Kanzi Tamaru is associated with Dr. Honda at the Imperial University. Manuscript received August 11, 1927.

tions[2] have been reported, in which hot quenching media such as water, aqueous solutions of NaCl, acids or alkalis and oils were used. In these cases, the heated specimen comes in contact with the hot liquid, which easily vaporizes and covers the surface of the specimen, and hence the cooling action of quenching media becomes slow and gives rise to a heterogeneous structure. This phenomenon becomes more marked, as the temperature of the bath rises. Oknoff[3] used mercury 59 degrees Fahr. (15 degrees Cent.), lead 618 degrees Fahr. (326 degrees Cent.), glycerine 32 degrees Fahr. (0 degrees Cent.) and coal tar 32 degrees Fahr. (0 degrees Cent.) etc. as quenching media and measured the specific volume of quenched steels.

In order to avoid the bad effect of water vapor on the surface of the specimen, the present writers used a nitrate salt mixture, which is easily fused; but as this mixture melts first at 270 degrees Fahr. (132 degrees Cent.), for lower temperatures mercury was used. Salt baths[4] have hitherto been used for the purpose of tempering or uniform heating, but not as a quenching media.

According to the above quoted theory of quenching[5], austenite transforms into pearlite through martensite, irrespective of the cooling velocity, the martensite being an intermediate stage of this transformation. Hence it is not always necessary to obtain troostitic and sorbitic structures by tempering quenched steel at 570-930 degrees Fahr. (300 to 500 degrees Cent.); it can also be obtained by suitable slow cooling of austenitic steel. By slow cooling, austenite first transforms into martensite; and this change taking place at a higher temperature, the martensite changes again into troostite or sorbite.

Since the change austenite to martensite is accompanied by an expansion and the change martensite to troostite by a contraction the result is that when these two changes take place side by side, there is no abrupt change of volume and hence there is also little chance of quenching cracks being formed.

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[2]Hitzel, *Journal* of the Iron and Steel Institute, 1, p. 359, 1916.
Pilling and Lynch, *Transactions,* American Institute of Mining and Metallurgical Engineers, Sept., 1919, p. 2347.
French and Klopsch, TRANSACTIONS, American Society for Steel Treating, August, 1924, p. 171.

[3]Oknoff, *Revue de Metallurgie,* 22, p. 181, 1919.

[4]Sam Tour, TRANSACTIONS, American Society for Steel Treating, Nov., 1922; Aug., 1924.

[5]Honda, loc. cit.

Quenching Media

The undesirable behavior shown by solutions and oils in quenching operations has already been explained in the foregoing section. Molten salts and mercury have no such defect, their vaporization being much more difficult. A salt mixture of the composition 65 per cent KNO_3 and 35 per cent $LiNO_3$ melts at 270

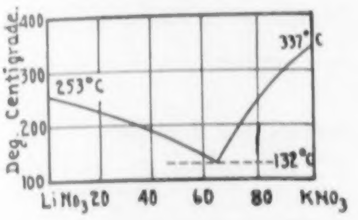

Fig. 1—Curve Showing Melting Point of a Salt Mixture of 65 Per Cent KNO_3 and 35 Per Cent $LiNO_3$ to be 270 degrees Fahr. (132 degrees Cent.)

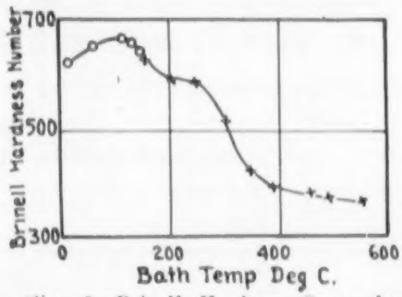

Fig. 2—Brinell Hardness Curve for Specimens Immersed 1 Minute in the Liquid Bath.

degrees Fahr. (132 degrees Cent.) (Fig. 1) and hence can be used as a quenching medium above 300 degrees Fahr. (150 degrees Cent.), for lower temperatures mercury may be utilized. As mercury and nitrates differ in their specific heat and thermal conductivities, the hardness of steels quenched in the above two media at the same temperature may somewhat differ from each other, but the actual test on this point confirmed that these two media gives nearly the same hardness as long as the temperature of the medium remained the same as is shown in Table I.

Table I
Brinell Hardness Numbers of Specimens Quenched in Various Media

Quenching Media	Temperature, °Cent.	Temperature, °Fahr.	Time, Minutes	Brinell Hardness Number
Mercury	160	320	10	642
Mercury	200	392	10	620
Nitrate Bath	148	300	10	642
Nitrate Bath	200	292	10	617
Mercury	150	302	20	627
Nitrate Bath	150	302	20	627
Mercury	150	302	1	637
Nitrate Bath	150	302	1	627

Two specimens were used in each test.

These tests were made on a Swedish carbon steel of the following composition:

	Carbon	Manganese	Silicon	Phosphorus	Sulphur
Per Cent	0.89	0.19	0.34	0.028	0.015

Hardness Tests

Specimens in the form of a short square rod, 15 × 15 × 20 millimeters, were heated at 1470 degrees Fahr. (800 degrees Cent.) for 15 minutes and quenched in mercury or the salt bath. After keeping them in the bath for a definite period of time, they were taken out, and the hardness was measured by a Brinell machine; the presence or absence of cracks and the structures being also examined. Table II and Fig. 2 illustrate the results of tests for the

Table II

0.9 Per Cent Carbon Steel Immersed for 1 Minute

Quenching Media Kind	Temp., °C.	Structure of Steel	Brinell Hardness Number	Cracks
Mercury	15	Martensite	617	Crack
Mercury	65	Martensite	647	Crack
Mercury	115	Martensite	664	Crack
Mercury	130	Martensite	652	No
Mercury	150	Martensite	637	Crack
Nitrate Bath	150	Matrix : Martensite; Grain Boundary : Boundary Troostite	627	No
Nitrate Bath	203	Matrix : Martensite; Grain Boundary : Boundary Troostite	589	Crack
Nitrate Bath	244	Matrix : Martensite; Grain Boundary : Boundary Troostite	582	Crack
Nitrate Bath	293	Matrix : Martensitic Troostite; Grain Boundary : Boundary Troostite	507	No
Nitrate Bath	339	Troostite	410	No
Nitrate Bath	387	Troostite	387	No
Nitrate Bath	453	Troostite	370	No
Nitrate Bath	490	Sorbite, small amount of Ferrite	364	No
Nitrate Bath	547	Sorbite	358	No

Two specimens were used in each test.

specimen which was kept for 1 minute immersed in the liquid. Table III and Fig. 3 are for the specimen immersed in the liquid for 10 minutes, Table IV and Fig. 4 are for the specimen immersed for 20 minutes.

The hardness curve in Fig. 2 has a maximum at about 230 degrees Fahr. (110 degrees Cent.). Thus steels quenched in mercury at 230 degrees Fahr. (110 degrees Cent.) are harder than those quenched at room temperature. This means that the cooling velocity of the specimens quenched at room temperature is too great to allow austenite to transform completely into martensite and therefore a certain portion of it remains unchanged, but when quenched in the bath at 230 degrees Fahr. (110 degrees Cent.), the velocity of cooling is just appropriate and the transformation austenite to martensite is completed. The course of the curve at higher temperatures shows the softening of the steel caused by the decomposi-

tion of alpha and beta martensites at about 320 and 570 degrees Fahr. (160 and 300 degrees Cent.) respectively, in good agreement with the result reported by one of the present writers.[6] The same phenomenon is also seen in Figs. 3 and 4. For the sake of com-

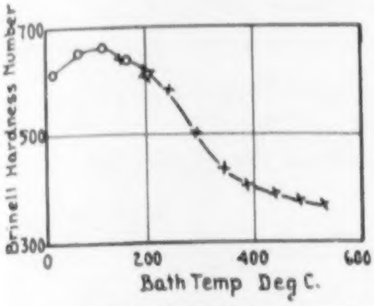

Fig. 3—Brinell Hardness Curve for Specimens Immersed in the Liquid for 10 Minutes.

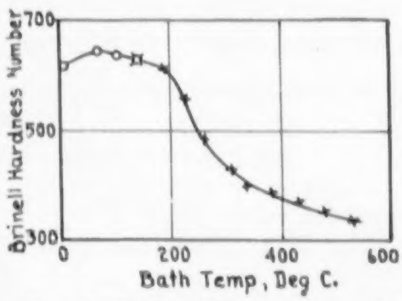

Fig. 4—Brinell Hardness Curve for Specimens Immersed in the Liquid for 20 Minutes.

parison, these curves are all drawn in the same diagram Fig. 5; a thin dotted curve reproduces the result of hardness tests of the same steel quenched in water followed by tempering at various

Table III

0.9 Per Cent Carbon Steel Immersed for 10 Minutes

Quenching Media Kind	Temp., °C.	Structure of Steel	Brinell Hardness Number	Cracks
Mercury	14	Martensite	617	Crack
Mercury	64	Martensite	652	Crack
Mercury	113	Martensite	664	Crack
Mercury	160	Martensite	646	No
Mercury	200	Martensite	620	No
Nitrate Bath	148	Matrix : Martensite; Grain Boundary : Boundary Troostite	642	No
Nitrate Bath	200	Martensite	617	No
Nitrate Bath	244	Matrix : Martensite; Grain Boundary : Boundary Troostite	583	No
Nitrate Bath	292	Matrix : Martensitic Troostite; Grain Boundary : Boundary Troostite	501	No
Nitrate Bath	339	Matrix : Troostite; Grain Boundary : Boundary Troostite	435	No
Nitrate Bath	387	Sorbitic Troostite	399	No
Nitrate Bath	434	Sorbite, small amount of Ferrite	385	No
Nitrate Bath	481	Matrix : Sorbite; Grain Boundary : Ferrite	373	No
Nitrate Bath	528	Matrix : Sorbite; Grain Boundary : Ferrite	364	No

Two specimens were used in each test.

temperatures, which experiments have been carried out by one of the present writers[7]. We see from Fig. 5 that the decomposition temperature of martensite falls with the increase of time interval

[6] Tamaru, Science Reports, Tohoku Imperial University, Sendai, Japan, XV, p. 829, 1926.

[7] Tamaru, loc. cit.

during which the specimen was kept immersed in the bath. This decomposition takes place in the vicinity of 645 degrees Fahr. (340 degrees Cent.) for the specimen quenched in water, but at about 515, 445 and 430 degrees Fahr. (270, 230 and 220 degrees Cent.) for the specimens quenched in the salt bath and kept for 1, 10 and 20 minutes respectively in the bath. The fact that the curve for 20

Table IV
0.9 Per Cent Carbon Steel Immersed for 20 Minutes

Quenching Media Kind	Temp., °C.	Structure of Steel	Brinell Hardness Number	Cracks
Mercury	15	Martensite	617	Crack
Mercury	80	Martensite	642	Crack
Mercury	110	Martensite	632	Crack
Mercury	150	Martensite	627	Crack
Nitrate Bath	150	Matrix : Martensite; Grain Boundary : Boundary Troostite	627	No
Nitrate Bath	196	Matrix : Martensite; Grain Boundary : Boundary Troostite	615	No
Nitrate Bath	235	Matrix : Martensite; Grain Boundary : Boundary Troostite	555	No
Nitrate Bath	254	Matrix : Martensite; Grain Boundary : Troostite	484	No
Nitrate Bath	310	Matrix : Troostite; Grain Boundary : Boundary Troostite	428	No
Nitrate Bath	339	Troostite	390	No
Nitrate Bath	387	Sorbitic Troostite	371	No
Nitrate Bath	481	Sorbite	351	No
Nitrate Bath	582	Sorbite	338	No

Two specimens were used in each test.

minutes lies below the curve for 10 minutes is due to the effect of a greater degree of tempering caused by a longer immersion in the hot bath. Steels quenched in water and tempered show a hardening effect caused by recrystallization at about 805 degrees Fahr. (430 degrees Cent.), but in the case of steels quenched in the hot bath, the above phenomenon is not present.

The steels quenched in the hot bath at a temperature up to 300 to 390 degrees Fahr. (150 to 200 degrees Cent.) were martensitic in their structure for all the immersion intervals mentioned above. While in a range of the bath temperature 570 to 750 degrees Fahr. (300 to 400 degrees Cent.), for 1-minute immersion, the structure was troostitic, in a range 805 to 985 degrees Fahr. (430 to 530 degrees Cent.), it was sorbitic. For a 10-minute immersion, martensite was obtained in a wider range of temperature than in the case of 1 and 20-minute immersions, that is, up to 390 degrees Fahr. (200 degrees Cent.), and the hardness in the former case was greater than the latter. From Tables II to IV it is seen

that if the temperature of the bath is below 250 degrees Fahr. (120 degrees Cent.), cracking always takes place, because, in such severe quenching, the outer portion of the specimen contains more arrested austenite than in the inner portion and consequently is subject to a large tension due to the difference in the specific volumes of austenite and martensite[8]. In a range 300 to 390 degrees Fahr.

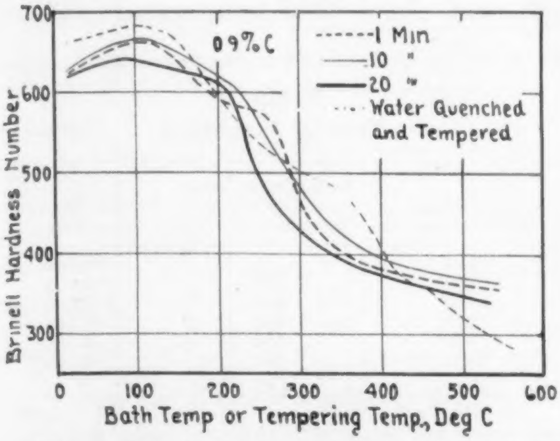

Fig. 5—Brinell Hardness Curves for Specimens Quenched in Water Followed by Tempering at Various Temperatures.

(150 to 200 degrees Cent.), the cooling velocity of the outer portion is so moderate that no arrested austenite is present and the inner portion contains only a very small amount of troostite; hence the outer portion of the specimen is subject to compression and cracks are difficult to form. In this case the structure of the inner portion is martensitic, containing only a small amount of boundary troostite, and although it is very hard, cracking seldom takes place. This result is very important for preventing quenching cracks.

Mechanical Tests

Tensile Strength and Elongation. Steel rods of 15 millimeters in diameter and 140 millimeters in length were heated at 1470 degrees Fahr. (800 degrees Cent.) for 30 minutes and quenched in the salt baths of different temperatures given in Table V and were kept immersed in the bath for 10 minutes. Test pieces which underwent such heat treatment are denoted by the letter B in the tables and the figures. Steels heated likewise and quenched in water and then tempered at different temperatures in the salt bath

[8]Honda and Idei, Science Reports, Tohoku Imperial University, Sendai, Japan, IX, p. 491, 1920.

for 30 minutes are marked by the letter W. From the materials thus treated, test specimens, of 7 millimeters in diameter and 70 millimeters in gage length, were prepared and tested by means of an Olsen testing machine. The results are given in Table V and Fig. 6. Between 570 and 790 degrees Fahr. (300 and 420 degrees Cent.) (Fig. 5), the hardness of specimens W is greater than that of specimens B, but above this temperature, the opposite is the

Table V
Tensile Properties

Specimen	Quenching Temperature, °C.	Bath Temperature or Tempering Temperature, °C.	Tensile Strength, lbs. per sq. in.	Elongation, Per Cent
B-380..........	800	380	174,000	7.5
W-380..........	800	380	209,000	6.5
B-440..........	800	440	162,000	7.4
W-440..........	800	440	183,500	7.0
B-560..........	800	560	153,000	8.0
W-560..........	800	560	146,500	10.0

Two specimens were used in each test.

case. These results agree satisfactorily with the tensile tests illustrated in Fig. 6, that is, specimens W are stronger than specimens B in the range of 750 to 840 degree Fahr. (400 to 450 degrees Cent.), but weaker above 1040 degrees Fahr. (560 degrees Cent.). This fact is explained from the structure of these specimens:—If the specimens marked W are heat treated at a temperature below 805 degrees Fahr. (430 degrees Cent.), they contain much troostitic sorbite and less ferrite, but if they are heat treated above 1040 degrees Fahr. (560 degrees Cent.), they contain less sorbite and more ferrite, than the specimens marked B. These differences of their structures give rise to the difference in tensile strength and elongation in the specimens W and B. When tempered below 715 degrees Fahr. (380 degrees Cent.), both specimens W and B showed no true tensile strength owing to the accidental break which is probably due to the presence of internal stress. The tensile strength curves of tempered steels obtained by Hanemann and Jung[9] have a maximum at 570 to 750 degrees Fahr. (300 to 400 degrees Cent.), showing less strength below 570 degrees Fahr. (300 degrees Cent.).

Impact Resistance. A Charpy impact testing machine of 30 kilograms capacity was used. Test pieces were similarly heat

[9]Oberhoffer, *Das Technische Eisen* (Zweite Auflage), 468.

treated as those for the tension test; their dimensions are shown in Fig. 7. The results of the test are given in Table VI and Fig. 7. For specimens W, the tempering effect is incomplete up to 605

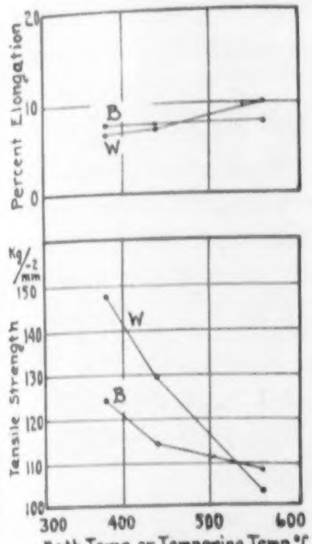

Fig. 6—Curves Showing Tensile Strength and Elongation of Specimens Tempered at Various Temperatures.

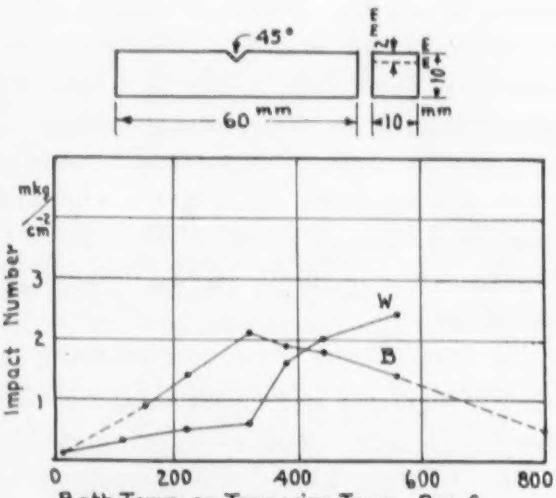

Fig. 7—Type of Impact Specimen and Curves Showing Impact Number of Samples Tempered at Various Temperatures.

degrees Fahr. (320 degrees Cent.), and hence they show a small impact resistance, but if they are tempered at higher temperatures,

Table VI
Charpy Impact Values

Specimen	Quenching Temperature, °C.	Bath Temperature or Tempering Temperature, °C.	Charpy Impact Figure, kg/mm²
W- 15	800	15	0.1
W-110	800	110	0.4
B-150	800	150	0.9
B-220	800	220	1.5
W-220	800	220	0.5
B-320	800	320	2.1
W-320	800	320	0.6
B-380	800	380	1.9
W-380	800	380	1.6
B-440	800	440	1.8
W-440	800	440	2.0
B-560	800	560	1.4
W-560	800	560	2.4
B-800	800	Furnace cool from 800° C.	0.6

Two specimens were used in each test except B-150, in which one was used.

the impact resistance increases by virtue of the formation of minute particles of troostite or sorbite. For specimens B, the impact

resistance increases with the temperature of the salt bath up to 605 degrees Fahr. (320 degrees Cent.) due to the formation of troostite; but if the temperature of the bath is raised above 605 degrees Fahr. (320 degrees Cent.), the amount of pearlite formed increases and the impact resistance decreases markedly, specimens B getting more brittle than specimens W. The formation of pearlite is attributed to the fact that when the temperature of the salt bath is high, the cooling velocity through A_1 is so slow that some pearlite is formed. It will be seen from Fig. 7 that the impact figure of a specimen (B — 800°) which has been cooled in a furnace from 1470 degrees Fahr. (800 degrees Cent.), and has a pearlitic structure is extremely small, being only 1/4 to 1/5 as strong as that of sorbite.

Summary

1. Mercury and a salt mixture 65 per cent KNO_3 and 35 per cent $LiNO_3$ were used as a hot quenching medium.

2. Carbon steel (0.9 per cent carbon) was quenched in mercury below 300 degrees Fahr. (150 degrees Cent.), and in the salt mixture above 300 degrees Fahr. (150 degrees Cent.). The hardness, tensile strength, elongation and impact resistance were measured.

3. Hardness tests showed a maximum at about 230 degrees Fahr. (110 degrees Cent.). The beginning of the decrease of hardness caused by the decomposition of beta martensite moves to a lower temperature with the increasing time of immersion.

4. The tensile strength of a quenched specimen decreases with the rise of the bath temperature. Specimens quenched in the salt bath below 930 degrees Fahr. (500 degrees Cent.) are weaker than those quenched in water and followed by tempering, but are stronger when the bath temperature rises above 930 degrees Fahr. (500 degrees Cent.).

5. The impact resistance increases gradually up to 605 degrees Fahr. (320 degrees Cent.) bath temperature, but decreases at higher temperatures.

6. Martensitic structure was obtained by quenching the specimens in the hot salt bath up to 390 degrees Fahr. (200 degrees Cent.), troostitic structure in a range of 570 to 750 degrees Fahr. (300 to 400 degrees Cent.) and sorbitic structure above 750 degrees Fahr. (400 degrees Cent.).

(Continued on Page 125)

THE ECONOMIC VALUE OF NICKEL AND CHROMIUM IN GRAY IRON CASTINGS

By D. M. Houston

Abstract

The constitution and primary structure of cast iron are essentially the same as in steel, except for the amount and form of the contained carbon. The elements and conditions that influence the form of graphite and the constitution of combined carbon are discussed, in particular,—

Silicon is a graphitizer and softener; Chromium is a carbide former and, therefore, a hardener; Nickel is a carbide destroyer and a matrix hardener.

In making use of nickel and chromium in foundry mixtures, the author gives approximate equivalents to assist in determining the nature of the structure that may be obtained from an alloy mixture compared with one of plain iron or semi-steel. These approximate equivalents are given as follows,—

One point of carbon equals 3 points of silicon in reducing chill;

One point of carbon equals 6 points of nickel in reducing chill;

One point of carbon equals 3 points of chromium with respect to chill.

The practical applications of nickel-chromium gray iron are described and such examples cited as,—

(a) Heavy section and pressure work
(b) Diesel engine liners where uniform hardness is essential
(c) Forming dies, jigs and tool fixtures
(d) Automobile cylinders.

The importance of base composition as an economic factor is dwelt upon at length, and illustrations are given of nickel-chromium mixtures developed with a proper base composition whereby the Brinell hardness was uniformly increased twenty to thirty points without impairing machinability at approximately the same cost per pound as plain cast iron.

A paper presented before the ninth annual convention of the society held in Detroit, September 19 to 23, 1927. The author, D. M. Houston, a member of the society, is foundry engineer, development and research department of the International Nickel Company, New York City. Manuscript received June 18, 1927.

NO introduction is needed today for a discussion of alloy cast iron. The metallurgical effects of the different alloys on cast iron have been described in general[1] and the effects of nickel and chromium, in considerable detail.[2,3] It is the purpose of this paper to describe how these effects may be utilized in a practical manner by foundries in producing gray iron castings of substantially improved properties and at a minimum cost. It must be recognized that the demand for alloy cast iron products will increase only as quality standards are developed and maintained. The same standards of control must be applied here as in the alloy steel field to maintain uniformity and dependability of product.

The structure of plain and of alloy iron—It will first be worth while to review the feature effects of nickel and chromium additions, particularly as they are exhibited in the microstructure. The constitution and primary structure of cast iron are essentially the same as in steel, except for the amount and form of the carbon. As is well known the carbon of the iron may occur as fine or coarse graphite, as carbide, or as pearlite. Its form and distribution is profoundly affected by the presence of other metalloids and of alloys. Specifically, the important elements that influence structure in gray iron (plain or alloyed) aside from total carbon, are *silicon,* the function of which is to graphitize or gray the iron, and within certain limits is a softener; *chromium,* which is a carbide-forming agent and a hardener; and *nickel,* which is a carbide destroyer and a matrix hardener. The effects of these elements, separately and in combination, are well illustrated in the accompanying photomicrographs.

The "balancing of" alloy mixtures—It will be clear from the photomicrographs that alloy as well as plain iron may vary in structure from one extreme, wherein carbides are absent but the graphite is coarse and open, to the other, wherein the graphite structure is fine but carbides may be present in excess. The combined carbon is low in the former and high in the latter. The former iron has a low chilling tendency, the latter, a high one. It is always one of the most important tasks of the foundryman

[1]W. H. Hatfield, Cast Iron in the Light of Recent Research.

[2]R. Moldenke, Effects of Nickel and Chromium on Cast Iron, *Transactions,* American Institute of Mining and Metallurgical Engineers, Volume 68, page 930; 1922.

[3]T. H. Wickenden, J. S. Vanick,—Nickel and Nickel-chromium in Cast Iron, *Transactions,* American Foundrymen's Association, volume 33, page 347; 1925.

to balance his mixture properly so that he may secure the maximum degree of graphite refinement in any given casting or section, together with a full pearlitic matrix as free as possible from excess carbides.

Although each of the important elements mentioned above has its own peculiar and characteristic manner of affecting gray

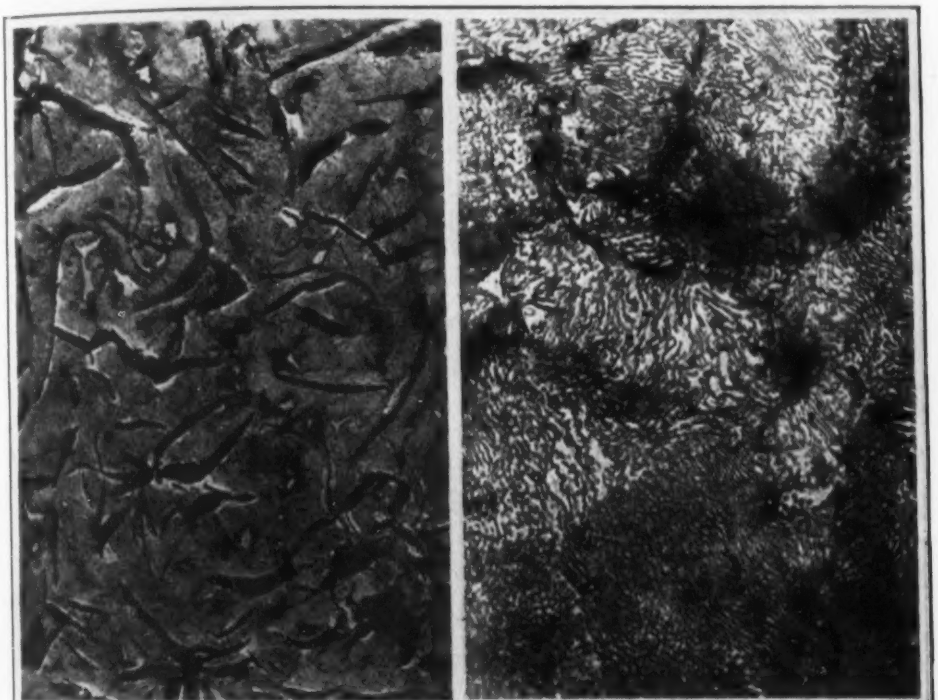

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Fig. 1—Photomicrograph of Plain Cast Iron of High Total Carbon, Showing the Usual Mechanical Mixture of Impure Steel and Flake Graphite Breaking Up the Steely Matrix Into Irregular Areas Indicating Inferior Strength and Density. The Ground Mass Shows a Few Irregular Light Patches of Iron Phosphide Eutectoid. 100x. Fig. 2—Same as Fig. 1. The Structure Consists of Alternate Pearlite and Graphite Areas. The Hooked Shaped Light Areas are Carbide. The Presence of Pearlite, Ferrite, Graphite and Carbide is Not Unusual in Irons of this Composition. 500x. Analysis:—TC 3.75 Per Cent; Si 2.03 Per Cent; Phos 0.60 Per Cent; S 0.087 Per Cent; Mn 0.70 Per Cent.

iron structure, they may be usefully and roughly compared in respect to their effect on chilling tendency. Indeed it is possible to roughly construct a table of equivalence for them, which is of considerable value to the foundryman in adjusting his alloy as well as plain mixtures.

1 point carbon = 3 points silicon in reducing chill
1 point carbon = 6 points nickel in reducing chill

1 point silicon = 2 points nickel in reducing chill
1 point silicon neutralizes 1 point chromium in respect to chill.

No claim for extreme accuracy is made for those given here, but they are sufficiently close to enable the metallurgist to make use of them until he shall have ascertained what small variation

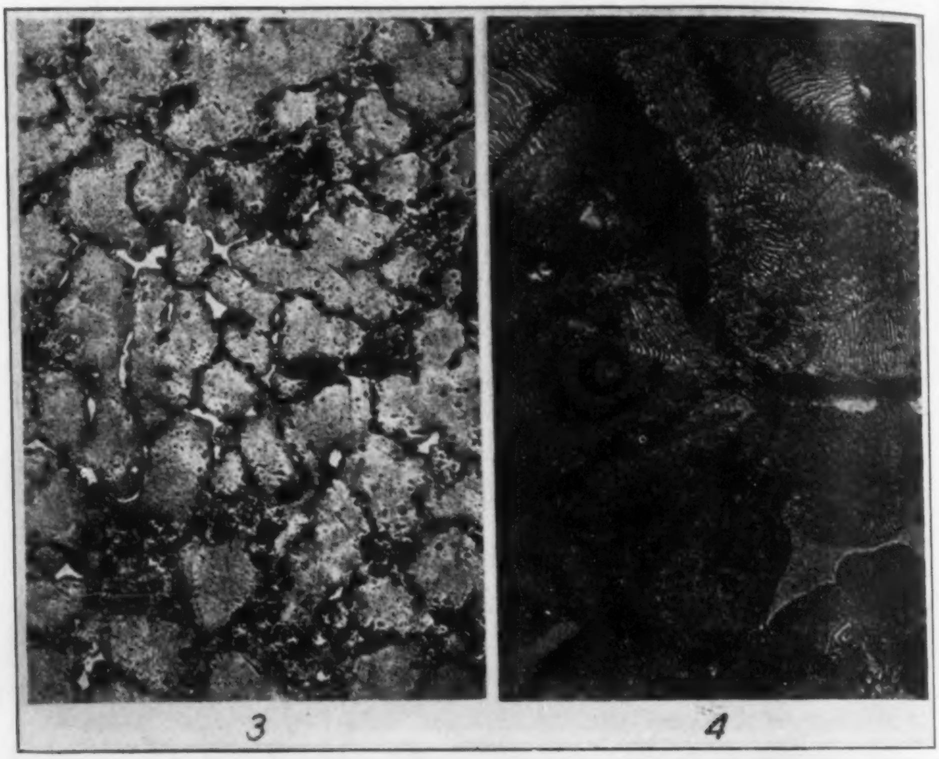

Fig. 3—Photomicrograph of Plain Cast Iron of Low Total Carbon Showing the Usual Mechanical Mixture of Impure Steel and Graphite. The Whole Structure Shows Finer and Better Graphite Distribution, Indicating a Stronger and Denser Material than in Fig. 1, Plate 1. This is Due to the Lower Total Carbon and Silicon. There is No Evidence of Phosphide Eutectoid Because of the Low Phosphorus and the Areas are Virtually Free from Ferrite, but Carbide is Present More Abundantly Because of the Low C and Si. The White Areas in the Photomicrograph are Iron Carbide and are the Cause for Poor Machinability. 100x. Fig. 4—Same as Fig. 3. Shows Detail of Pearlite, Graphite and Carbide. The Matrix Corresponds to that of About 0.70 Carbon Steel. 500x. Analysis:—TC 3.19 Per Cent; Si 1.24 Per Cent; Phos 0.15 Per Cent; S 0.085 Per Cent; Mn 0.60 Per Cent.

from the values given will be necessary to meet the particular conditions in his own foundry. The use of such "equivalents" may be illustrated by an example.

One of the serious problems that confronts most foundries making a large variety of castings is to produce relatively small quantities of metal of suitable composition for a particular casting without being obliged to run a special mixture in the cupola. For example,—a foundry may be regularly making a 1.75-2.00

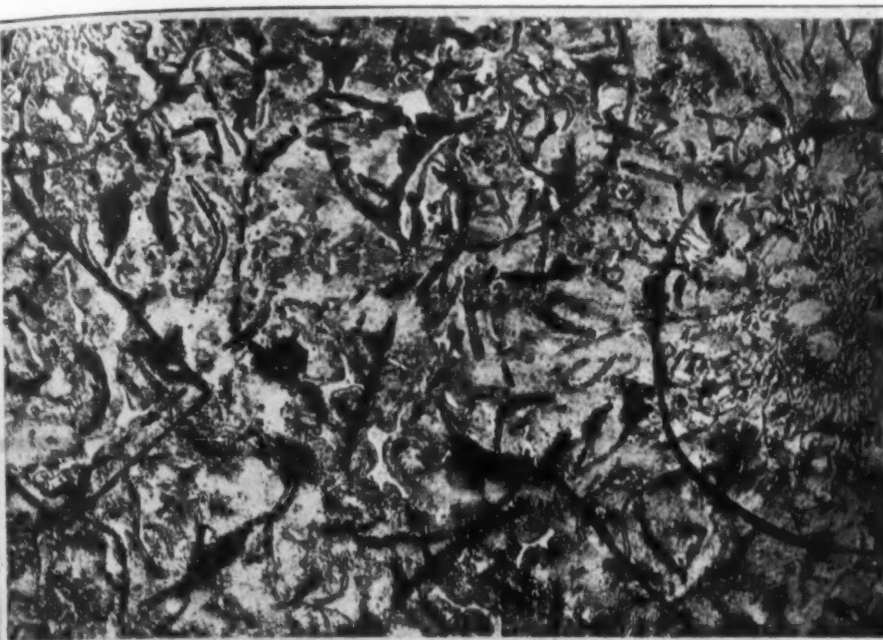

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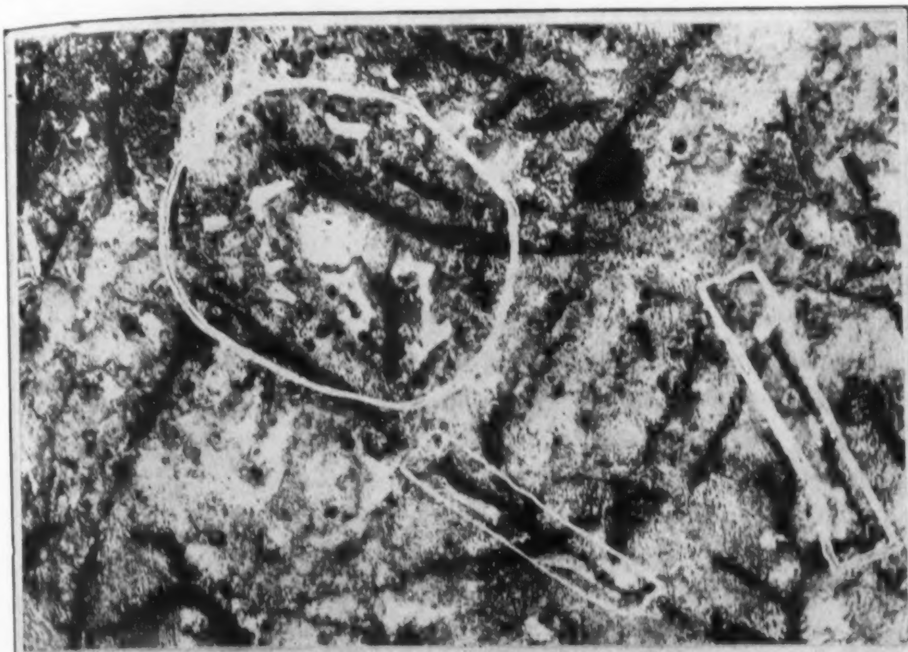
Fig. 5—Photomicrograph of a Mild Semi-Steel Showing Ferrite-Graphite Concretions Marked (O) in Different Stages of Growth. Iron Carbide Residues Persist in Large Interrupted Network (------------), at Times Concentrated Into Knots (□). The Network Contributes to Tool Wear; Knots are Responsible for "Hard Spots". The Graphite (the Black Areas) are Reasonably Fine and Well Distributed, Indicating Very Good Strength. 150x. Fig. 6—Same as Fig. 5. Shows a "Close Up" of the Iron Carbide Knots in the Pearlitic-Sorbitic Matrix Which is the Prevailing Structure,—the White Hooked Shaped Areas in the Picture were Carbide. These Carbide Inclusions are Dislodged in Metal-to-Metal Wear and Act as an Abrasive Between the Wearing Parts, Especially in Cylinders, and are Responsible for Much of the "Scoring" in Cylinders. 500x. Analysis:—TC 3.30 Per Cent; Si 2.34 Per Cent; Phos 0.19 Per Cent; S 0.076 Per Cent; Mn 0.65 Per Cent; Cr 0.09 Per Cent (an Impurity in the Charge).

per cent silicon iron having a total carbon of 3.40 per cent. This metal is well suited to their general run of work but is unsuited for a casting that must be made that should carry approximately 1.25-1.50 per cent silicon. Since the total carbon will be unchanged, the method of procedure will be as follows:—The necessary silicon reduction is 0.50 per cent and since 1 point of chromium balances approximately 1 point of silicon, the desired results may be obtained by making an addition of 0.50 per cent chromium. However, as illustrated in Figs. 7 and 8, this amount of chromium added to the metal will be combined as chromium carbide, and will be difficult to machine. Consequently, these carbides must be broken down. According to the tabulation above, 1 point of chromium will require 2 points of nickel; so that the composition in the finished product will be,—total carbon 3.40 per cent, silicon 1.75 per cent, chromium 0.50 per cent and nickel 1.00 per cent. This casting will not only have added grain-refinement and greater strength than a 1.25 per cent silicon iron but it will also have the machinability of a 1.75 per cent silicon iron, because, as far as chill is concerned, 0.50 per cent chromium added is balanced by 1.00 per cent of nickel. The phosphorus should be below 0.30 per cent.

Some Industrial Applications of Nickel-Chromium Iron

The accompanying illustrations are chosen to illustrate the manner in which foundries are utilizing alloys today in the production of high quality castings. One foundry doing jobbing work specializes on a 3.35 per cent total carbon, 2.00 to 2.10 per cent silicon semi-steel mixture, but frequently is called upon to make blank gears having sections up to 2½x6 inch and require, according to their practice, a 1.50 per cent silicon mixture. These gears come in on small orders and in order to take care of the business satisfactorily without changing the base mixture it was found necessary to make an addition of 0.50 per cent chromium and 1.00 per cent nickel.

Another foundry is often required to make hydraulic pressure work castings requiring a stronger and denser metal than they can secure with a standard semi-steel mixture. They use an iron analyzing as follows,—total carbon 3.40 per cent, silicon 1.50 to 1.60 per cent, sulphur 0.085 per cent, phosphorus 0.22 per cent, manganese 0.70 per cent. To this mixture is added 0.35



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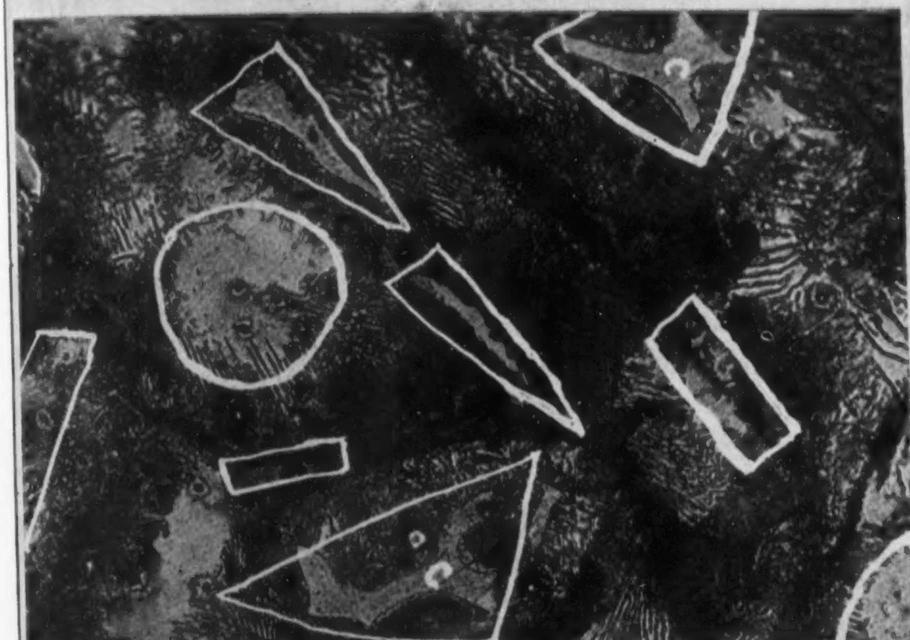

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Fig. 7—Photomicrograph of High Silicon, High Chromium Iron. The Presence of Particles of Free Ferrite Adjoining Graphite Flakes and the Occurrence of Knots of Carbide, Both of These Constituents at Times Appearing Side by Side, Indicating an Extremely Heterogenous or Unbalanced Structure. The Opposite Character of These Extremely Soft and Extremely Hard Constituents Illustrates the Constant Risk of Segregation Resulting in Soft and Hard Spots in the Same Iron. Compare with Fig. 5 $\boxed{\text{Ferrite}}$ O = Carbide Knots. 150x. Fig. 8—Same as Fig. 7, Showing Detail of Structure Shown in Fig. 7. A Pearlitic Matrix Studded with Carbide △ Sometimes in Knots and in the Presence of Ferrite □. An Unusual Feature is the Ferrite Rim Adjoining a Carbide Island "C". These Features Indicate That Any Number of Troubles Might Develop, Such as Soft and Hard Spots, Sponginess, Cracks, Leakage and Rapid Wear. 500x. Analysis:—TC 3.30 Per Cent; Si 2.68 Per Cent; Phos 0.18 Per Cent; S 0.080 Per Cent; Mn 0.66 Per Cent; Cr 0.39 Per Cent.

per cent chromium and 0.70 per cent nickel, resulting in a strong and dense metal, well suited to the requirements of the job and without changing their general mixture. The additions are made to the melted metal and only enough metal is so treated to pour the job at hand.

Mitigating the Effects of Lack of Uniformity of Pig Irons—The subject of the quality of pig irons is one that has received much attention in recent years. Many foundrymen and metallurgists contend that pig irons made now are of poorer quality than those made a decade ago, and attribute to this fact many of their metal troubles. On the other hand, pig iron producers maintain that the quality of pig irons has steadily improved and that the reason for this complaint is that the quality standards of castings have been raised. Consequently, a more careful selection of brands of irons and better cupola practice are the only requirements for meeting these demands. Nevertheless, many investigators, both here and abroad, agree that the presence of primary graphite in gray iron is the cause of many of our difficulties and the complete elimination of this element as primary graphite by many special processes has resulted in irons possessing superior merit. These processes will undoubtedly find their place in industry according to their value. However, it is not commercially economical in many cases to make use of special methods when only a slight improvement in grain-refinement will meet the requirements.

It has been found that chromium added to molten iron will first of all enter into combination with the uncombined carbon and form stable chromium carbides. In order to secure a commercial casting with good machining properties, it is necessary to break down these carbide formations and to secure a full pearlitic matrix, which is accomplished effectively by the addition of nickel, in the ratio of 2 of nickel to 1 of chromium. Silicon cannot be used effectively here because ferrite and graphite will result instead of pearlite and graphite.

In this way primary graphite and kish may be controlled to a large extent by the use of proper percentages of chromium and nickel, and hence the quality of pig iron becomes a less important factor, thereby permitting a wider range of selection of that material. It may be mentioned that the same results may

be obtained by reducing the silicon content and adding an amount of nickel equal to twice that by which the silicon is reduced. This latter method is to be preferred for light and medium sections, the former for heavy sections.

The importance of the selection of such brands of pig iron as will uniformly produce a close grain structure will be recognized by every foundryman who has been called upon to make pressure-tight and machine tool castings. Frequently the same brands of pig iron made up with the same amount of steel scrap and foundry returns and analyzing the same in every particular will show an open grain, when an apparently identical car of iron used previously had produced a satisfactory structure. The difference in structure is due to the presence of a larger amount of primary graphite and can be controlled by the use of nickel and chromium as pointed out previously. The additions should be made to the liquid iron, because the influence of these alloys are more definite when so added.

Chromium and Nickel in Heavy Sections—With plain gray iron it is extremely difficult, if not impossible, to produce a uniform grain structure in heavy sections, because at the slow cooling rates of such sections plain iron carbides break down into graphite and ferrite when the temperatures are above 1100 degrees Fahr. Thus, in such sections of plain iron, the combined carbon is lowered substantially and the casting has a coarse structure with low hardness and strength. This condition can be almost entirely corrected by the proper use of nickel and chromium largely due to the restraining effect of chromium upon primary graphite formation and the stability of chromium carbides in the upper temperature range. The amount of chromium that will be necessary to create the desired amount of stable carbides will depend upon total carbon, silicon and the rate of cooling. The amount of nickel that must be used is that amount which is just sufficient to break down the carbides. On account of the long cooling period through relatively high temperatures in heavy sections, the ratio of nickel to chromium may often be reduced from 2 of nickel to 1 of chromium to 1 of nickel to 1 of chromium, in consequence of which the cost of the metal will be correspondingly reduced. To illustrate:—a foundry making an ammonia compressor head in which a very heavy section of metal was ad-

jacent to a valve seat found that it was almost impossible to produce a machinable casting that did not leak in that heavy section. An analysis of that portion showed the combined carbon to be 0.18 per cent, but when 0.45 per cent chromium and 0.75 per cent nickel was used in the same mixture the combined carbon was 0.52 per cent and the casting was more easily machined than without the alloy addition. Care should be exercised in making chromium additions in excess of 0.50 per cent because chromium shrinkage may develop. This shrinkage may be effectively controlled by increasing the ratio of nickel.

Diesel Engine Liners—For the same reason, namely, the stability of chromium carbides at slow rates of cooling, the use of chromium and nickel is recommended in Diesel engine cylinder liners, requiring a minimum hardness of 200 Brinell. It is necessary to resort either to a very high nickel content in a low total carbon and low silicon base iron, or to a nickel-chromium mixture in which the total carbon and silicon contents play an important part. If the total carbon is high (3.40-3.50 per cent), it will be necessary to run the silicon in the neighborhood of 0.90 per cent in conjunction with from 0.40-0.60 per cent chromium and from 1.25-2.00 per cent nickel. This should produce a casting ranging from approximately 200 Brinell in the middle section of the casting to about 240 Brinell on the edges. The edges, however, will not be white but will be gray and machinable. When a lower total carbon is used, it will be necessary to make a corresponding adjustment of the silicon content but the alloy content will remain virtually the same as given for the higher total carbon material.

In either one of these mixtures, by increasing the silicon content to approximately 2.00 per cent and adding from 3.50-4.00 per cent nickel with approximately 0.50 per cent chromium, it is entirely possible to produce a Brinell hardness almost identical throughout the entire length of the liner wall. This method, however, is not recommended as being the most economical, but unless very good control over the melting practice is maintained with the lower alloy content process, the higher nickel content method may be more economical due to the fact that it is more "fool proof".

Forming Dies, Jigs and Tool Fixtures—Forming dies used

on production work are valuable in accordance with the service rendered before repair or failure overtake them, so that it is of great importance, not only as a matter of life of the die but also as a matter of maintaining perfect contour, that a material with a high resistance to wear is made use of for this class of casting. The resistance to wear of chromium-nickel irons has been so well demonstrated in forming dies, cams, etc., that it is only necessary to mention them.

In formulating a mixture for this class of work, the amount of alloys required will depend largely on the amount of total carbon. Experience has indicated that 3.00-3.10 per cent total carbon is the most satisfactory with a silicon content of about 2.00 per cent, depending upon the size and section of the casting, and from 0.75-1.00 per cent chromium and from 2.75-3.00 per cent nickel. Castings made from this material and machined —not ground—for metal-to-metal wear invariably increase the life over plain gray iron or semi-steel many times. The phosphorus content should not exceed 0.20 per cent.

The Use of Nickel and Chromium in Automobile Cylinders

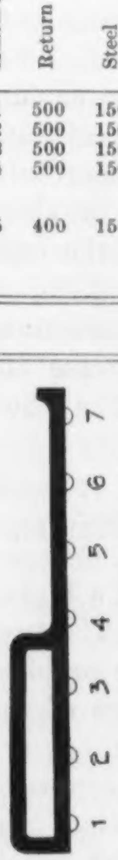
Automotive engineers are more and more demanding a higher hardness on automobile cylinder walls and valve seats. The producer of these cylinders is continually confronted by the problem of hard edges and difficult machinability as the hardness of the cylinder walls is increased. While the cylinder wall sections are not heavy, on account of design and coring, they cool comparatively much more slowly than other parts of the casting. On account of this, cylinder walls in plain iron are invariably much softer in the piston ring travel portion (due to the jacket core being located in that section) than in any other section. This, of course, is due to the breaking up of the iron carbides in the same manner as described under chromium and nickel in heavy sections.

The addition of from 0.3 to 0.4 per cent chromium and from 0.6 to 0.8 per cent nickel usually produces a minimum Brinell hardness of 200 in the cylinder wall without decreasing machinability, when used in a base composition giving 160 to 170 Brinell hardness number. However, the hardness values obtained will depend somewhat upon the design and the composition of the

Table I
Materials Used in Making up Charge

Mixture No.	Return Scrap	Steel	Federal	Zenith	Mayari	Silvery	Ounces Ferro-Cr	Lbs. Ni Shot	Si	TC	S	Ni	Cr
ALLOY IRON									ANALYSES				
1	500	150	312½	...	...	37½	12	4.66	2.05	3.45	0.095	0.53	0.14
2	500	150	312½	...	...	37½	15	4.66	2.05	3.32	0.096	0.41	0.15
3	500	150	312½	...	...	37½	35	4.66	2.11	3.43	0.095	0.51	0.25
4	500	150	312½	...	...	37½	77	4.66	2.07	3.34	0.094	0.47	0.37
PLAIN IRON													
5	400	150	225	100	50	75	..	...	2.34*	3.30	0.076	0.055	0.09

*Nickel and chromium are impurities.



Cast iron Cylinder Block Section Showing Position of BHN Determinations on Bore.

Table II
BHN Data on Cylinder Walls

Location of BHN on Cylinder	Mixture No. 1	Mixture No. 2	Mixture No. 3	Mixture No. 4	Mixture No. 5
1	167	184	198	227	179
2	177	177	187	190	143
3	170	170	198	198	131
4	164	170	184	194	131
5	177	177	181	196	137
6	174	178	202	198	163
7	177	190	184	221	181
Average BHN	172	178	191	203	152
Additional Cost	6 Cents	12 Cents	18 Cents	35 Cents	

base metal so that these alloy percentages under some conditions may need to be varied somewhat.

A Study of Automobile Cylinder Alloy Irons—That a better structure having greater strength and density and having a greater resistance to wear can be secured by the use of alloys in gray iron is now accepted generally by metallurgists. The chief objection to their use commercially is the increased cost. It was the purpose of the investigation conducted as shown by the accompanying data to develop a base composition requiring only a low alloy content to secure improved structures and properties equivalent

to those of higher alloy irons in which the base composition had not been properly adjusted to alloy additions.

The importance of the base composition as well as the nickel-chromium ratios are shown in Tables I and II. Cylinders of mixture No. 1, with 2.05 per cent silicon and 3.45 per cent total carbon having a 3 nickel to 1 chromium ratio, gave a variation in

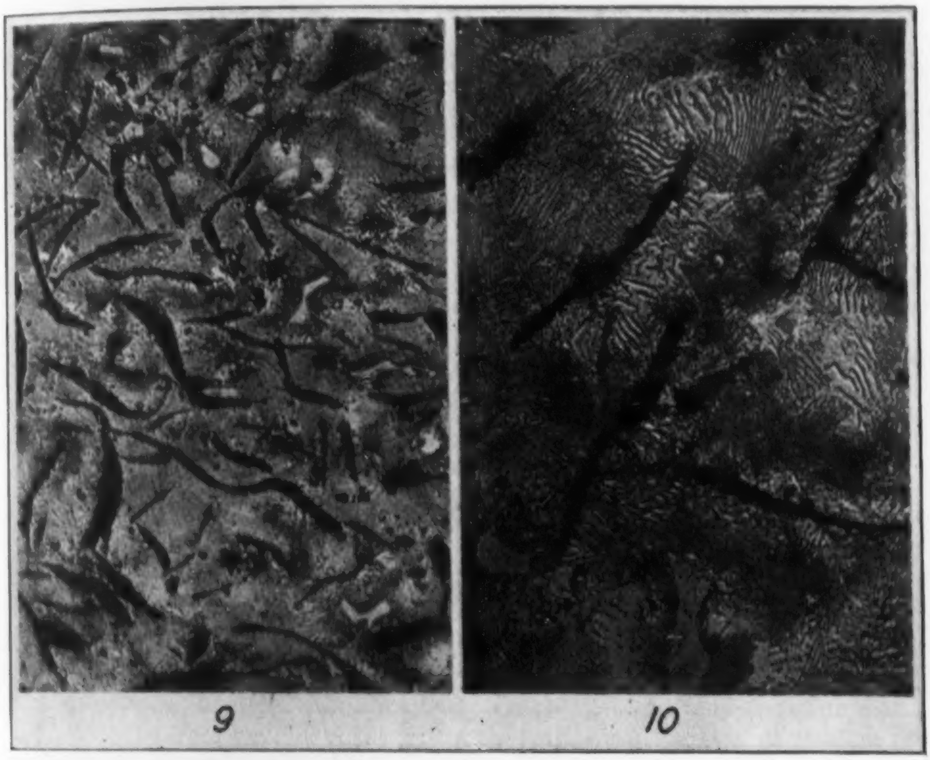


Fig. 9—Photomicrograph Showing the Graphite Distribution and Pearlitic Matrix with Only a Spattering of Free Carbide and Free from Ferrite or Knotty Structure. 150x. Fig. 10—Same as Fig. 9. A "Close Up" on the Structure Shown in Fig. 9. Matrix is Pearlitic and Sorbitic and Spots of Carbides That are Nearly Broken Up, Indicating Uniformity of Structure and Resistance to Wear as Well as Being Strong and "Close Grained". 500x. Analysis:—TC 3.32 Per Cent; Si 2.05 Per Cent; Phos 0.18 Per Cent; S 0.096 Per Cent; Mn 0.62 Per Cent; Ni 0.41 Per Cent; Cr 0.15 Per Cent.

Brinell hardness number of 13. Mixture No. 2 with practically the same base but a 2¾ nickel to 1 chromium ratio, showed a variation of 20 Brinell hardness number. Mixture No. 3 having virtually the same analysis as No. 1 except that the ratio is 2 of nickel to 1 of chromium gave a difference of 21 Brinell hardness number. Mixture No. 4, practically the same as mixture No. 2 but with a 1¼ nickel to 1 chromium ratio gave a difference of 37 Brinell hardness number. Mixture No. 5, the plain iron, showed the maximum difference of 50 Brinell hardness number. While

Mixture No. 4 would seem the most attractive from the hardness point of view, Mixture No. 1 is more uniform in hardness which is characteristic of the 3 of nickel to 1 of chromium ratio. Mixture No. 3 is next in uniformity of hardness, but has a 2 of nickel to 1 of chromium ratio. No. 2 gave 6 point higher average hard-

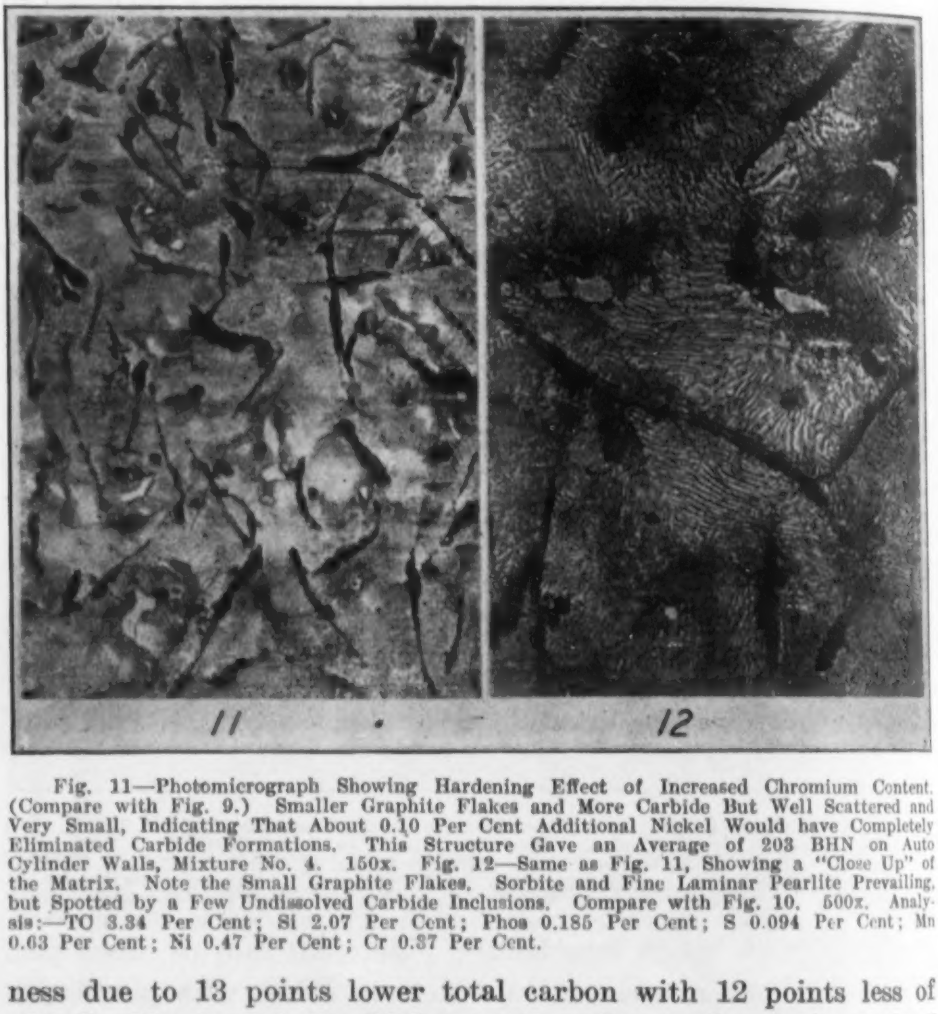


Fig. 11—Photomicrograph Showing Hardening Effect of Increased Chromium Content. (Compare with Fig. 9.) Smaller Graphite Flakes and More Carbide But Well Scattered and Very Small, Indicating That About 0.10 Per Cent Additional Nickel Would have Completely Eliminated Carbide Formations. This Structure Gave an Average of 203 BHN on Auto Cylinder Walls, Mixture No. 4. 150x. Fig. 12—Same as Fig. 11, Showing a "Close Up" of the Matrix. Note the Small Graphite Flakes. Sorbite and Fine Laminar Pearlite Prevailing, but Spotted by a Few Undissolved Carbide Inclusions. Compare with Fig. 10. 500x. Analysis:—TC 3.34 Per Cent; Si 2.07 Per Cent; Phos 0.185 Per Cent; S 0.094 Per Cent; Mn 0.63 Per Cent; Ni 0.47 Per Cent; Cr 0.37 Per Cent.

ness due to 13 points lower total carbon with 12 points less of nickel. No. 3 with the higher total carbon and a ratio of 2 of nickel to 1 of chromium seems to indicate that total carbon is a factor in uniformity of hardness values.

The ideal economical mixture then would be Mixture No. 1 having a silicon content of perhaps 1.85 or 1.90 per cent and the 3 nickel to 1 chromium ratio, and this will furnish Brinell hardness number values equivalent to Mixture No. 4 at about the same price of plain iron.

Figs. 9 and 10 are photomicrographs of Mixture No. 2. Figs. 11 and 12 are photomicrographs of Mixture No. 4. The lower silicon content recommended for Mixture No. 1 will reduce the size of the graphite and give a better structure than No. 4.

The materials in the mixture as formulated for plain iron

Table III
Cost of Mixtures per 1000 Lbs.

Materials Used	Mixture No. 1	Mixture No. 2	Mixture No. 3	Mixture No. 4	Mixture No. 5
Return Scrap	4.00	4.00	4.00	4.00	3.20
Steel	1.35	1.35	1.35	1.35	1.35
Federal	3.07	3.07	3.07	3.07	2.21
Zenith	....	....	....	....	1.16
Mayari	....	....	....	....	.88
Silvery	.54	.54	.54	.54	1.88
Total Plain Iron	8.96	8.96	8.96	8.96	9.88
Ferrochromium	....	.10	.20	.48	....
Nickel	1.63	1.63	1.63	1.63	....
Cost of Alloys	1.63	1.73	1.83	2.11	....
Total Cost	10.59	10.69	10.79	11.07	9.88
Return Recovery 40% of Alloy	.65	.69	.73	.84	....
Net Cost	9.94	10.00	10.06	10.23	9.88
Net Additional Cost of Alloy Addition	.06	.12	.18	.35	.00

Costs	Per Ton	Per Lb.	Costs	Per Ton	Per Lb.
Zenith	26.07	.01164	Mayari	39.18	.0175
Federal	22.02	.00983	Nickel	.....	.3500
Steel	18.00	.009	Ferrochr.	.....	.1000
Return	16.00	.008	Silvery	32.29	.01441

cylinders, in Table III analysis and hardness values of which are shown in Tables I and II, have a value per 1000 pounds of $9.88.

The materials used in the mixture for the base composition in the alloy iron have a value per 1000 pounds of $8.96, or a saving per 1000 pounds of $0.92 on the base composition over that used in plain iron. The cost of alloys used to treat 1000 pounds of Mixture No. 4, which was adopted as having machinability equivalent to plain iron or Mixture No. 5 and having an average Brinell hardness of 203 as against 152 in the plain iron, as shown in Table I, amounted to $2.11. Sixty per cent (or $1.27 worth of alloy) was consumed in good castings and 40 per cent (or 84 cents worth) was reclaimed as foundry returns, accordingly representing a credit of 84 cents on the total cost of $11.07, making the total cost $10.23 or 35

cents per 1000 pounds greater than plain iron which if used with the base composition previously employed would have resulted in a net cost of $1.27 per 1000 pounds.

Another important feature of the application is that the Brinell hardness in the two mixtures; viz., No. 4 having a 2.07 per cent and No. 5 having 2.34 per cent silicon content, would not be equivalent with the same alloy content because a part of the chromium is consumed in counteracting the effect of the higher silicon, so that to secure hardness values in No. 5 equivalent to those in No. 4, a higher alloy content will be necessary. According to the equivalents given under metalloid equivalents, 0.64 per cent chromium and whatever nickel is necessary to break up the carbides formed by the chromium addition would be necessary. A fair basis of calculation would be 0.60 per cent chromium and 0.80 per cent nickel, which when added to the No. 5 plain iron mixture cost would add 86 cents for chromium and $2.80 for nickel, making a total of $3.66 per 1000 pounds of metal for alloy content alone. From this may be deducted 40 per cent of $3.66 or $1.46 for recovery from foundry returns, making the cost of alloys in the castings $2.20. This amount must be added to the base cost of Mixture No. 5 (see Table III) $9.88 plus $2.20 equals $12.08 per 1000 pounds and the results are no better than those secured from the lower alloy content Mixture No. 4 (Table III) costing $10.23 per 1000 pounds.

ACKNOWLEDGMENT

The author gratefully wishes to acknowledge the valuable assistance of Messrs. Paul D. Merica, Thomas H. Wickenden, James S. Vanick and Francis C. Coyle of the Development and Research Department, The International Nickel Company; M. J. Gregory and F. Shipley of Lakey Foundry and Machine Company; Messrs. Hoertle and Shaw of Continental Motors Corporation; A. E. Hageboeck of Frank Foundries Corporation; Messrs. Harrington and Wright of Hunt-Spiller Manufacturing Company, and many others who assisted in securing much of the data contained in this paper.

DISCUSSION

R. S. McPHERRAN: We have all listened with interest to this instructive paper by Mr. Houston. The paper is full of information and well worth while.

Any comment I would make would be in a friendly spirit and more in the way of suggestions. For example, Mr. Houston, in a praiseworthy effect to simplify or systematize his ideas on the comparative effect of various elements, would seem to me to have gone too far and made the lines too rigid. In my experience, the comparative relations between silicon and carbon, for example, are not capable of being reduced to the positive formula given.

It would seem to me also that in discussing material, while Mr. Houston gives his results, he should also give his process of reasoning. It may be true that nickel improves the wearing properties of automotive cylinders and heads, but we see here no experiments or tests leading to this conclusion. It would be most instructive and convincing if some author would give a series of tests covering a number of cylinders and heads made of similar composition and hardness, with and without chromium or nickel, and all subjected to the same severe service for a considerable period. These castings to be measured before and after test to determine respective wear and comparative deterioration of the valve seats.

The same could be applied to Diesel liners. Are there actual service tests on these liners with and without chromium or nickel? We have tried putting nickel into a number of castings and find it very advantageous to do so for machining purposes. We are now running tests for comparative wear, but are not as yet in position to report.

Written Discussion: By Edward R. Williams, Vulcan Mold and Iron Company, Latrobe, Pa.

Mr. Houston has made a fine contribution to the practical applications of alloy cast iron. Most foundrymen, even though recognizing the superiority in quality of alloy iron, have been hesitant about adopting it as standard practice because they have felt it would mean an increased cost. With the low margin of profit prevailing in the gray iron business no great increase in selling price would be justified. It could not be put through without a large amount of educational and pioneer work. Mr. Houston has shown that alloy iron of a superior quality can be produced at little if any increase in cost.

This is mainly brought about by the utilization of higher percentages of scrap, preferably steel scrap. The effect of higher sulphur content resulting is counteracted by the alloys and we obtain a cast iron with increased strength, toughness and better machinability.

In making alloy iron it is necessary for the foundryman to decide what kinds and percentages of alloys he shall use. This is dependent on the section and size of the casting. Mr. Houston has given a means of establishing these percentages or grades of iron which would otherwise cost the foundry considerable in experimental work.

There are several additions which I would like to make to Mr. Houston's paper which seem to me of importance in the alloy iron field. The temperature at which iron is melted has a great deal to do with the physical properties of the casting. According to a theory recently developed by Prof. Dr. H. Hanemann the highest temperature which the molten iron reaches determines the size and shape of the graphite crystals and hence decides to a great extent the mechanical properties of the resulting castings. In part Prof. Hanemann

states that at normal melting temperatures not all of the carbon is dissolved in the fusion but exists as graphite particles distributed throughout the molten mass. When cooling begins these graphitic particles act as nuclei on which the balance of the graphite crystallizes when the temperature of crystallization is reached. The resulting graphite crystals are therefore large and flaky. As the temperature of the molten iron increases, more and more of these graphite nuclei or germs are dissolved until when the temperature of 2730 degrees Fahr. is reached, all the graphite is in solution. Upon cooling the graphite does not precipitate until the crystallization temperature of about 2000 degrees Fahr. is reached when graphite in the eutectic state is formed. This eutectic graphite is of the fine-grained, nodular form and as its crystallization is not dependent on the rate of cooling, castings of any size may be produced which will show these characteristics.

While I have not absolutely verified the accuracy of this theory, there has been plenty of evidence that it is correct.

Iron made in the electric furnace but tapped at a temperature below what would be considered normal and poured into test bars have evidenced the same open-grained structure with flaky graphite as cupola iron bars made of approximately the same analysis. The Brinell hardness was also practically the same. As the temperature of tapping the electric iron was increased a marked difference appeared, the bars showing a grain refinement, the graphite crystals becoming smaller and tending to the modular form. There was less variation in grain size from outside to center of bars and the Brinell hardness increased about 20 points.

It is not to be felt that electric melting is recommended for all alloy cast iron because most castings will not stand the increased cost that electric melting gives. However, for special applications where a large improvement in quality is desired the increase in cost may not be a factor. From a metallurgical standpoint, alone, electric melting seems to enhance the value of the alloys.

Mr. Houston discussed only castings which required machining and the best showing in alloy iron can probably be made in these types of castings. A pearlitic matrix is undoubtedly the best that can be found for machine castings as such a matrix has the highest strength, resistance to wear and fastest machinability.

It is the function of the alloys to produce this structure.

Castings for special purposes may contain higher percentages of alloys and may be either moderately machinable or unmachinable. Types of such castings would be equipment for steel plants, such as guides, rolling mill plugs, bending dies, piercing dies and plungers, crushing disks and rollers, pig machine wheels, etc. Other types requiring resistance to penetration, as well as erosion, are hammer dies and die blocks. Castings resistant to heat may have very large percentages of alloys, such as enameling furnaces, furnace doors, etc.

For alloy iron castings requiring very high quality it is important to have as low total carbon as possible to give toughness and high strength. This is, of course, hard to obtain in the cupola, but carbons under 3 per cent

and as low as 2 per cent are readily made in the electric furnace. Likewise, it is important to have the silicon as low as possible—even to one-half of one per cent, replacing the difference with nickel.

The electric furnace is an ideal melting medium for alloy cast iron, but it is not to be recommended unless a great increase in quality with high percentages of alloys is desired.

F. B. COYLE: The last speaker mentioned the use of cast iron for dies. While attending a meeting of the Toronto chapter of the American Society for Steel Treating about the first of October, 1927, this subject was actively discussed at several informal gatherings. One manufacturer in the Toronto district is using cast iron blocks containing 2.0 per cent of nickel for blanking dies. The operation consists in stamping out skate blades from 3/16-inch nickel-chromium sheet steel. The cutting edges of the dies are made of relatively small inserted tool steel blades. During 1926 when all-steel dies were used on this work the breakage consisted of at least one die per day. The total breakage for the year was stated to be about 350 dies. The cast iron dies were adopted at the beginning of 1927, and up to the first of September only one die had been broken. The exceptionally high compressive strength of this material (about 190,000 pounds per square inch) is probably a contributing factor.

The previous speaker also discussed the shape and distribution of graphite flakes. A few individuals have devoted considerable time to the study of this subject. This matter is intimately associated with the mechanism of the process of graphitization and the various alloying elements have a direct bearing thereon. It is hoped at the end of another year new and revealing information which has been obtained will be presented.

As regards casting temperatures, Piwowarsky has shown that high casting temperatures increases the strength of cast iron. For two years prior to the appearance of his paper the speaker supervised melting and pouring practice in a U. S. Government foundry during which time no casting (Diesel engine) was poured at a temperature less than 2600 degrees Fahr. The temperature of the molten iron as it was tapped from the cupola was between 2700 and 2800 degrees Fahr. Some heats were actually as high as 3000 degrees Fahr. This is purely a matter of cupola operation. However, it is the speaker's opinion that the temperature of 2700 degrees Fahr. does not necessarily produce the maximum results. Piwowarsky's able work was performed with crucible melts. The equilibrium conditions within a cupola or air furnace are entirely different. It has been the speaker's experience that results obtained by the cupola process are not always obtainable by the crucible process.

W. B. COLEMAN: I feel that the cast iron industry is greatly indebted to Mr. Houston and the International Nickel Company for the work that they have been doing on alloy cast iron. Most everybody knows that in the past years cast iron in general has been sliding backward. A great many of the engineers are going away from it, going over to steel. One of the great problems that has confronted engineers is the internal shrinkage in the iron castings. Here, I believe, nickel is going to play a great rôle. I have seen a number of castings made using nickel, but the foundryman must bear in

mind that it is not just a case of throwing the nickel in the ladle and getting good results, he must take into consideration the total carbon and silicon content as these must be in line for the casting that is to be made.

I have also observed that it is possible for physical properties to vary slightly when melting in different cupolas or using different raw materials and slight changes in composition might have to be made when using the same pattern at different foundries. When one considers the physical properties of steel many years ago, before alloys were used, and compare these figures with the alloy steels of today and the many conceivable combinations of alloy steels, I feel that the cast iron industry is going to go through the same change and that the surface has not been scratched by the use of alloy cast iron for industrial purposes. Using alloys in cast iron might be the step that will bring the cast iron industry back again to where it was and probably will make it a great deal more important in the engineering rôle. I think the work that Mr. Houston has been doing and is doing is going to be of great benefit to this development.

In Philadelphia the highest tensile test that I ever saw was about 40,000 pounds per square inch, and I saw Mr. Houston make a heat in Philadelphia about two weeks ago and saw the test bar pulled,—around 61,000 pounds per square inch.

The paper that Mr. Houston gave is on increased cost. To be sure, it may cost a little bit more, but some of this high strength can be obtained at a very little increase in cost, and probably in some sections, at no increase in cost, as it all depends upon the scrap market. The results that were obtained from that heat were remarkable. Pulley wheels where the tensile bar showed 61,000 pounds per square inch machined up just as easily at a 2.75 silicon iron, the rim of the wheel being possibly a quarter of an inch thick. So I think that the cast iron industry has a lot to look forward to in the work that Mr. Houston is doing.

E. L. Roth: The effect of these alloys depends, of course, on whether or not the alloy gets into the iron, and that is a point which has not been brought up and which I would like to touch on.

There are two ways of adding alloys to the cast iron, either in the cupola or in the ladle, and it has been my experience that the most efficient way to add the alloy is in the ladle, because one can take a definite amount of alloy and, having a known amount of iron, introduce the alloy, and obtain the desired analysis. In other words, if an engineer specifices 0.75 per cent nickel, the analysis can be controlled better by a ladle addition than it can when the alloys are added in the cupola, where the variables of blast, height of bed and so on may cause uneven melting of the charges. Since the temperature of the iron obtained from the cupola usually ranges from 2550 to 2770 degrees Fahr., nickel and chromium must be added to the ladle in the form of low melting alloys. Pure nickel melting at 2645 degrees Fahr. merely dissolves in the ladle and full recovery cannot be obtained, and the same is true to a more marked degree of pure chromium melting at 2770 degrees Fahr.

D. M. Houston: I might say that I have tried to make it clear in this paper that no claim for extreme accuracy is made for the equivalents given

here on the fourth page of the paper, and that there has been no desire on the author's part to presume that they are more than approximately correct within a comparatively narrow range.

For instance, an ordinary stove plate iron carrying 3.60 per cent total carbon with 3.00 per cent silicon, would give you about, according to my experience, the same hardness as 4.00 per cent total carbon with approximately 2.00 per cent silicon. Now, there are many conditions that the peculiar to different melting units that reflect themselves in the quality of material and also the relationships of these equivalents. I wish to say to Mr. McPherran that there was no forethought given to these equivalents. They are the result of many successful foundry mixtures that have been formulated which, when compared with the mixtures they have replaced, uniformly suggest the equivalents as given. They are not intended to extend over any wide range but to furnish ample latitude for the foundry metallurgist to formulate a mixture from an enlarged marked with the idea of keeping his costs down.

The results obtained from these ratios may require some adjustment in the mixture. My experience in using these equivalents in different foundries has been that I have never gone so far from the values aimed at as to produce uncommercial castings. They have not always worked out 100 per cent, and the intention was not that they were to be considered rigid.

The subject matter as stated in the first paragraph of this paper has to do with the affect of nickel and chromium in different base composition of varying analysis. Wear resistance has not been discussed. Only Brinell hardness values are discussed as they relate to base composition, alloy content and material costs. I quite agree with Mr. McPherran that the question of wear is contingent upon so many things that it requires a long time to accumulate or to get anything that is really authentic even under the best commercial conditions. There are so many variables that enter into the subject of wear that it is indeed very hard to even approximate the results obtained except in a very general way until the available data has been correlated.

ON A NEW METHOD OF QUENCHING STEELS IN A HIGH TEMPERATURE BATH

(Continued from Page 104)

7. When the temperature of the bath is below 250 degrees Fahr. (120 degrees Cent.), quenching cracks always form.

8. If the bath temperature be higher than 300 degrees Fahr. (150 degrees Cent.), any desired structure can be obtained at will without any fear of cracks.

9. The structure of steel quenched in the bath at about 930 degrees Fahr. (500 degrees Cent.) is sorbitic. Its mechanical property is not inferior to that quenched in water and tempered. This new method of heat treatment is more simple and less liable to produce cracks than the commonly used method of quenching and tempering.

FURNACE DEVELOPMENT IN HEAT TREATING AND FORGING

By W. M. Hepburn

Abstract

Incidents are cited which mark the start of the scientific heat treating period termed "the accelerated period of scientific development."

Scientific developments in furnace equipment are then related with particular reference to combustion, refractories, insulation, and temperature controls. Some outstanding modern gas-fired installations embodying the significant developments just noted are described:—

(1) *Continuous sheet steel normalizing furnace which handles steel mill production automatically and controls the temperatures and atmospheres to a degree of refinement equal to the most accurate heat treating furnace.*

(2) *A continuous carburizing furnace. Although new metallurgical developments are pending, the high thermal efficiency and accuracy of this latest furnace equipment demands the adaptation of the metallugical improvements to this type of furnace.*

(3) *Forging. The greatest immediate strides are anticipated in this field. Production methods applied to drop forging and the possibilities of the continuous types of furnaces enable great reductions in operating costs and also establish a standard of quality which will soon displace the present "cost only" standard.*

Conclusions point out how the trend of development has been to expand the problem far beyond that of simple inventions into that of advancing a science.

IT was only as far back as 1906 that the man who bet a million dollars on a poker hand was unwilling to take the risk of maintaining a metallographic laboratory and arbitrarily ruled out what he termed "the unnecessary laboratory work" of Albert Sauveur. Albert Sauveur is credited with being the first metallographist employed exclusively to practice his science. This fortunate contri-

A paper presented before the ninth annual convention of the society held in Detroit, September 19 to 23, 1927. The author, W. M. Hepburn, is vice-president in charge of engineering developments, of the Surface Combustion Company, Toledo, Ohio. Manuscript received July 13, 1927.

bution came from the steel industry in 1901. The events leading to the period around 1905 which we may term the accelerated period of scientific heat treatment centered around the steel requirements of the railroad industry and then gradually spread out and included the machine shops.

About 1905, the advent of the automobile began to be felt. The strides made in this industry in heat treating soon turned the orderly march of events into a precipitous flight, until today of all the industrial gas users, and there are approximately a million, the steel treaters are the outstanding class. In fact, to properly report the activities in this field, the services of a high class newspaper reporter should be utilized and not the tedious tactics of an engineer.

Heat Treating Conditions in the Automobile Plants

At the Ford Plant, in 1905, the heat treatment consisted of case hardening one or two parts. Vehicle springs were heat treated in a rough way in coal-fired furnaces. They were heated to what was termed a forging heat, formed, allowed to cool to about 1400 degrees Fahr. and quenched in oil. Today a typical 6 cylinder car has 190 parts to be heat treated. Considering the number of times each part must be heated in order to conform with the prescribed treatment we may say that 490 separate steel parts must be handled by the furnace equipment for each car.

Early Furnace Developments

An iron casing lined with firebrick and a fire box stoked with coal or coke was the means of furnishing heat at temperatures judged by the eye of the operator. An indicating pyrometer was used as an adjunct to the judgment of the operator. This arrangement sufficed for the small-scale production and the character of product then existing. The growth of competition demanded a high grade uniform product at minimum cost. This required quantity production on a precise schedule and the heat machine must therefore take its place as a link in the chain of fabrication.

Principles of combustion have been well established. Various equipment has been developed which can generate the heat units in any desired form whether that be a high degree of radiant heat

or in the form of convected heat or in fact any combination of these two. The predominance of one general type as is the case today is not due to the lack of combustion developments but rather to the lack of necessity for putting them into practice.

The automatic proportioning equipment is one of the mechanical expedients which has proven of particular value in the regulation of the rates of combustion. It is possible with the present

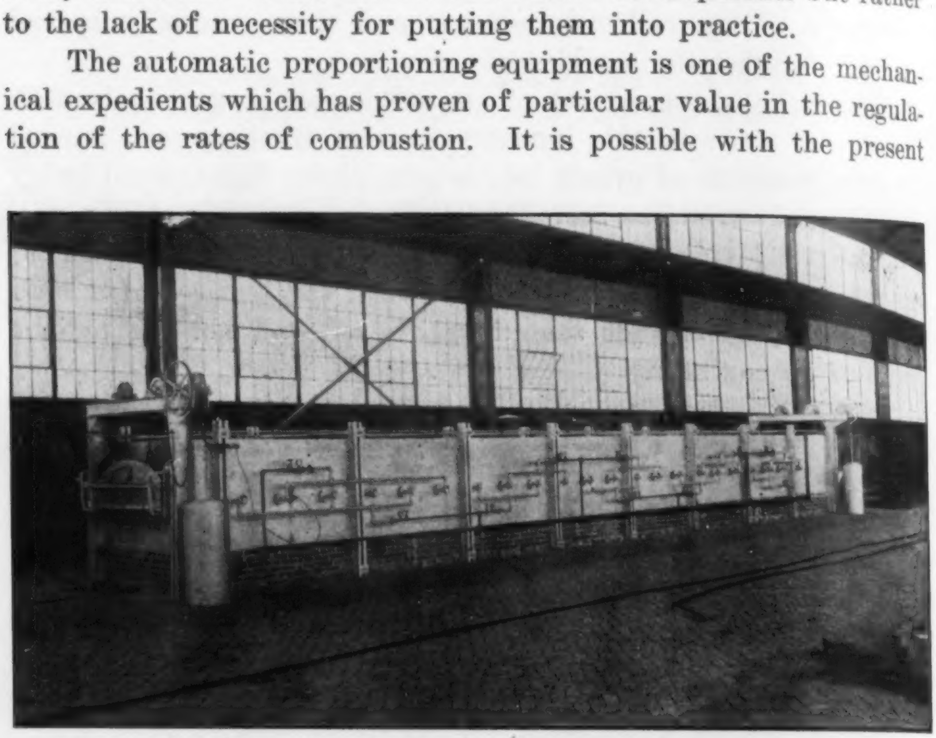


Fig. 1—Continuous Wire Patenting Furnace.

proportioning equipment to maintain the quantities of air in gas within limits of ½ of 1 per cent throughout the entire range of operation. This contribution not only materially lessened the flue gas losses which were incident to the former manually operated two valve controls but it also permitted operations that formerly could only be safely done in muffle furnaces to be performed in direct fired furnaces due to the positive control of the furnace atmospheres.

Fig. 1 shows one of the continuous wire patenting furnaces which well illustrates this principle. This furnace is fired direct, the strands of wire being exposed directly in the action of the products of combustion: The amount of scale formation was nearly half that which occurred in the furnace wherein the wire was completely muffled but which was equipped with the two valve controls.

Temperature Controls

From the indicating pyrometer with multi-point switch we pass through successive steps, such as the multi-point recorder and combination therewith of a manually operated signalling system between the instrument room and furnace operator for the manual

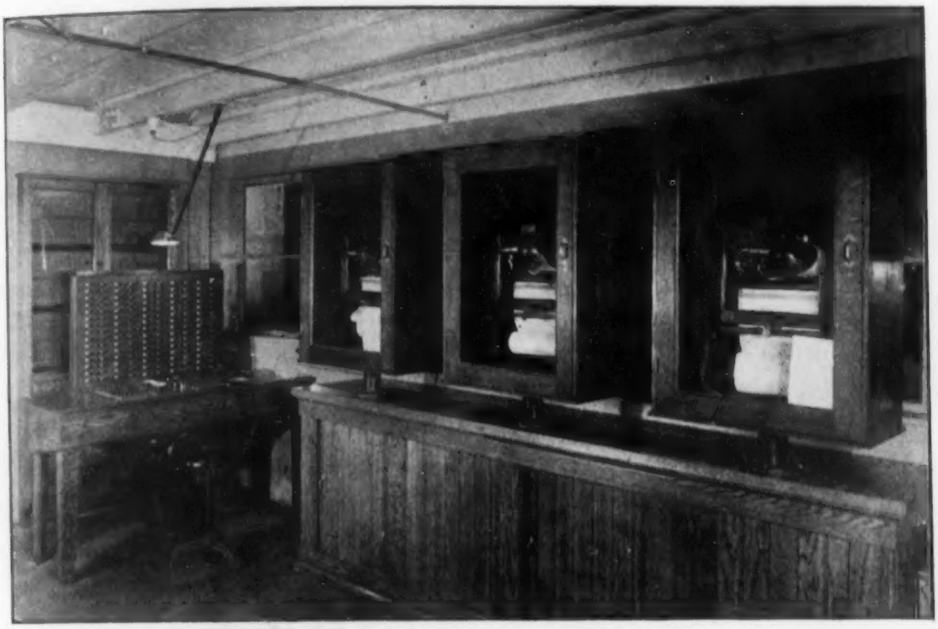


Fig. 2—Multi-Point Temperature Recorders and Manually Operated Central Signalling Stations—An Early Arrangement for the Control of Furnace Temperatures.

regulation of fuel feed, to the automatic system. Fig. 2 shows an installation of multi-point recorders and a manually controlled central signalling station. This equipment marked the advent of scientific temperature control. Automatic control of the temperature is essential and the time is not distant when every heat treating furnace, be it large or small, will be so equipped.

Refractories

In the field of refractories, the need for scientific precision is being felt. It is not a question of marketing a favorite brand of clay but supplying suitable refractories to meet the requirements of the particular applications. It is analogous to the application of the different alloy steels to their respective spheres of utility. The outstanding development was the production of silicon carbide re-

fractories because of their high thermal conductivity and high rigidity at extreme temperatures. It is appreciated that silicon carbide refractories are still far from being satisfactory, but at the same time, they have proven to be well worthwhile in many instances. Brick made from fused alumina bonded with clay are also a comparatively recent development and they are also applied to heat treating furnaces because of comparatively high thermal conductivity and high rigidity. While they do not oxidize like silicon carbide refractories, they spall much more readily and are not entirely satisfactory for that reason.

In fireclay refractories the very hard burned kaolin brick may be mentioned. With the ordinary grades of fireclay brick there has been a gradual trend toward increased density and higher burning temperatures which have made for longer service because of less deformation and shrinkage. While such gradual changes have not been as striking as some of the newer refractories, yet they have manifested themselves in reduced consumption of refractories per unit of furnace capacity. Sillimanite brick and mullite brick have not, as yet, been applied in any appreciable quantity to the construction of heat treating furnaces, but there is no doubt but that they will be.

Insulation

Insulation has been no small factor in the furnace development. The standards of thickness for heat treating furnaces have been steadily increased from the early 2½ inches to 13½ inches of today. As the insulating materials are improved particularly as regards shrinkage and strength at high temperatures, their application is increased many fold. Insulating brick are now available which will stand up satisfactorily at 2600 degrees Fahr. Door linings and, in fact, the complete lining of some furnaces can be constructed entirely of insulating brick. The old fallacy of trying to preserve refractories by cooling them is well exploded. Refractories can be made by the use of the proper constituents and temperatures of burning which will meet any obligation insulation imposes. The lack of insulation can be taken as a point of suspicion on any furnace.

Some of the Outstanding Developments

Normalizing. In the preparation of steel sheet which will

permit of deep drawing operations as required for such items as automobile fenders, the steel mills employ a heat treating operation termed "normalizing". This eliminates the first box anneal formerly used. The sheets are conveyed through the furnace individually on rotating discs. Fig. 3 shows a recent continuous sheet normalizer. This furnace is forced to meet more specific requirements than any other one heat treating operation. The

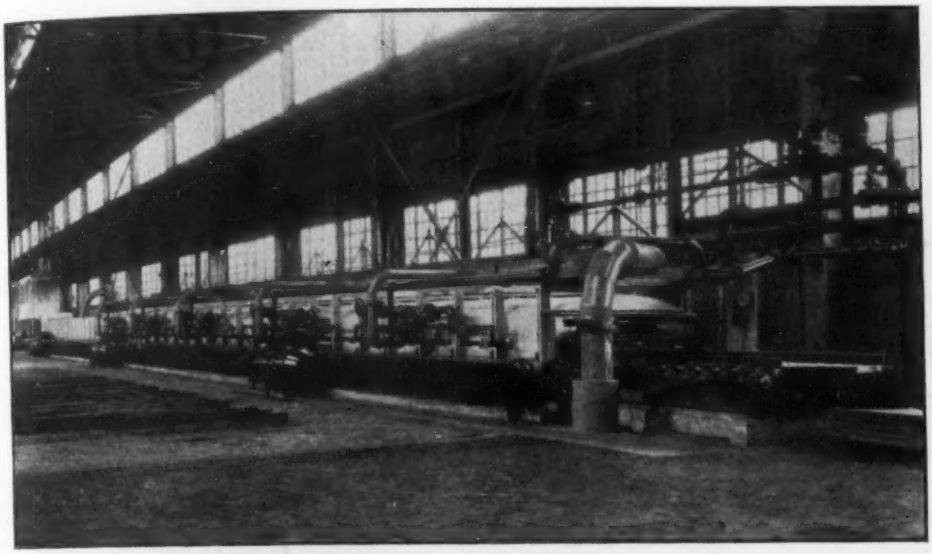


Fig. 3—Continuous Sheet Normalizing Furnace.

sheets are heated "on the fly", as it were, (in less than two minutes), the atmosphere must be maintained reducing to prevent the formation of scale, the temperature gradient is fixed for each foot of travel to produce the proper refinement, and the conveyor mechanism must deliver each sheet free of pits and scratches. Even with the heavy production of 4 tons per hour, it must heat the sheets with absolute uniformity. Gas is the fuel which has met the requirements in competition with coal, oil and electricity. There has been installed in the past two years gas-fired sheet normalizing furnace capacity sufficient to normalize 4 miles of 4 foot wide sheets every hour. The continuous sheet normalizer has shown the steel industry that gas can meet a greater combination of heating requirements than any other source of heat.

This fact is of considerable significance when we consider that the steel industry is the greatest factor in this matter of fuels and

furnaces. Even though the impetus came from the automobile manufacturing industry, it was the steel industry which instituted the scientific heat treating method. It has made contributions to gas manufacturing methods which have affected the entire gas industry. It uses two tons of coal for every ton of steel finished. This means approximately 100,000,000 tons per year, of which 60 per cent is converted into gas in some form. Today many steel

Fig. 4—Continuous Carburizing Furnace.

companies are projecting their future plans on the basis of a constant B. t. u. mixture of their blast furnace and coke gas as the base fuel for their metallurgical requirements.

Carburizing. Carburizing is an operation in which the depth of case is influenced by the temperature, length of time exposed, and the form of available carbon and simultaneously an unstable reaction occurs in the gradation of carbon content in combination with the steel. Considerable study is being devoted to this phase of metallurgy, chiefly in the way of reducing the time required for these reactions with the present pots and compounds.

Fig. 4 shows one of the most recent gas-fired installations. This type of furnace has an overall length of 27 feet, 5 inches, and a hearth width of 6 feet, 4 inches. The work consists mainly

of gear blanks carburized on an average to 0.035 inches depth, at a temperature of 1600 degrees Fahr. Three rows of boxes are arranged across the width of the hearth, the box dimensions being 18½ inches wide by 10 inches long by 12 inches deep. There are a total of 105 boxes in the furnace. The gross weight of the box is 250 pounds and the hourly capacity of the furnace is 1800 pounds gross.

The furnace is constructed of 9-inch firebrick, and 9 inches of insulation. The surface combustion principles of combustion are utilized in which the gas and air are intimately mixed in the proper proportions automatically and the resultant mixture burned intensively in small accurately molded combustion tunnels in the side walls. The heat evolved is then distributed by the particular arrangement of the burners, in this case, approximately eighty per cent being distributed under the hearth. The entire equipment is controlled by two automatic temperature controls, one controlling the inlet end and the other the soaking zone. A gross efficiency of more than 40 per cent is maintained.

Forging. Hammering was the first method employed by man for shaping metals. In spite of the fact that heating for forging is the oldest, it is the least advanced of all the metallurgical heating operations. The attention now being given to the forge shops, particularly in the automobile industry, indicates that the accelerated period of scientific development in this field has begun.

With the present slot forges, it is possible to heat sections even as small as ¾ inch round at too high a rate resulting in a large temperature differential between core and surface so that the surface may reach the melting point before the core becomes plastic enough for the forging operation. The advantages of uniform heating need not be stressed. To heat a piece of say three inch round stock uniformly throughout its section to forging temperature would require considerable time and, if done in the present oil fired forge furnaces, the surface would become scaled beyond the forging allowance. An improved forge design must provide for a high production, long soaking period and non-oxidizing atmosphere. A continuous type of forge furnace can be arranged to provide these conditions. In addition to the far reaching improvement in quality, operating costs have been reduced to such an extent, as evidenced by the following detailed analysis,

that the necessity of arranging the forge shops to incorporate these features is unquestionable. (See Table I)

Table I
Comparison of Operating Costs

(FORGING)

	4-Oil-Fired Furnaces	One Continuous Gas-Fired Furnace
Fuel—Production	$ 4,655.00	$ 3,476.00
Heating Up, Standby Losses	900.00	350.00
Labor	76,800.00	58,800.00
Maintenance	1,000.00	350.00
Steam, Light, Power	....	....
Die Life	....	....
Increased Production	....	....
FIXED CHARGES		
Hammers (4)	....	....
Presses	$ 64,000.00	$ 48,000.00 (2)
Restrike Hammers	....	....
Floor Space	6,000.00	4,800.00
Overhead	....	....
Total (not considering items left blank)	153,355.00	115,776.00
Anticipated yearly savings	....	37,579.00

PREMISES

1. 2,257,000 pounds stock per year = (1,400 pieces stock weighing 6.45 pounds per 16 hour day, 250 days per year).
2. Fuel—

Production

Oil 55 gallons per ton
Gas 5,500 cu. ft. per ton

Heating Up

Oil 1½ hrs. 4 fces.—8 gal. per hour
Gas 1½ hrs. 1 fce.—2,500 cubic feet

3. Cost of Oil—7½c per gallon
Cost of Gas—56c per 1,000 cubic feet
4. Labor—

Oil: 4 drop forgers at $1.50 per hour; 4 heaters at 90c per hour

Gas: 4 drop forgers at $1.50 per hour; 1 helper at 90c per hour; ½ furnace loader at 90c per hour

Direct labor overhead 100%

Regardless of whether the units are under production the full term of 250 days per year, the labor, fuel and maintenance are

relative to the time the units are in production. The possible savings of 30 per cent or more in fuel and the elimination of labor are only two items that justify the development. The unit, being under full automatic temperature control, can be operated at 50 per cent of capacity and practically the same ratio of savings will be maintained. When operating with only two drop forgers, the helper required for removing the flashing can be eliminated.

Fig. 5 shows the charging end and Fig. 6 the discharge end of one of the latest continuous type of forging furnaces. This particular furnace is used for heating crank shaft billets. It is equipped with automatic temperature controls which maintains the temperatures constant regardless of the production. The firing equipment is of the automatic proportioning type whereby the atmosphere is maintained slightly reducing. The combustion zones are so located that heat is applied to the work from both the top and bottom, thereby requiring approximately only half the length of time to heat the piece through as the slot type of forges heating only from above. Furthermore, the outgoing flue gases preheat the incoming work so that a high efficiency is maintained even at the forging temperatures. 25 billets have been forged from this furnace in 15 minutes with no deviation in temperature, each billet weighing 76 pounds. From this it is readily seen that the hammer crews are never held up waiting for hot steel.

Bolt Heading. Although the present tendency is to forge bolts cold, nevertheless, a certain grade of work and especially the larger sizes, requires the end heating operation as evidenced by the considerable number of rod end type of forges in operation throughout the country. In this operation, the stock is usually cut to the proper length and the end only heated. After the end has attained a forging temperature of about 2200 degrees Fahr., it is inserted in the bolt heading machine which upsets the end into the proper shaped bolt head.

The heading operation is a particularly difficult one due to the fact that a high production rate is desired and only a small portion of the stock exposed to the heat. This necessitates running forges at very high temperatures to maintain this schedule and seldom has gas been able to compete with the cruder and cheaper fuels in this application. The overhead system of firing directly against the work, using tunnel type burners has been advantageously ap-

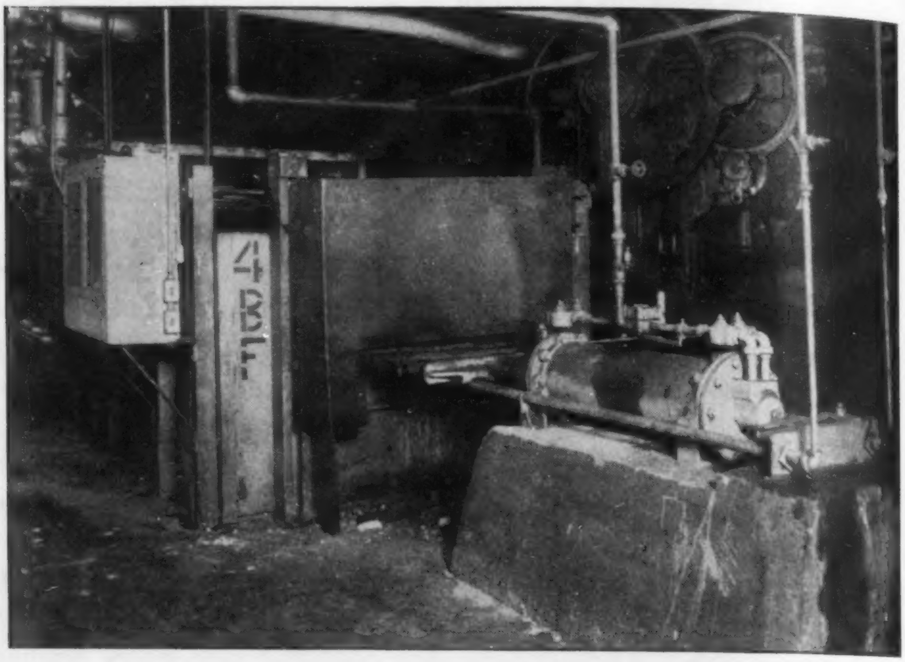


Fig. 5—Charging End—Continuous Crank Shaft Forging Furnace.

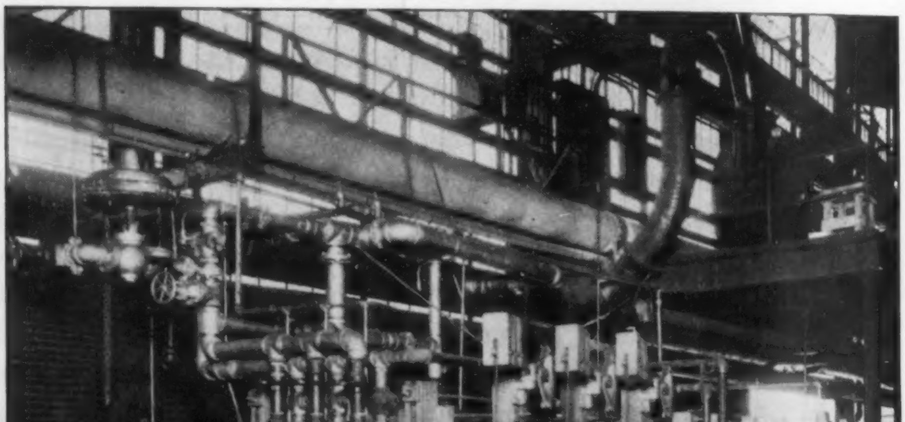


Fig. 6—Outlet End of Furnace Shown in Fig. 5.

plied to this class of work. Fig. 7 shows the arrangement worked out three years ago for one of the bolt manufacturing plants. This furnace made a very good showing in-so-far as the conversion of the present equipment is concerned. The overhead method of firing is particularly severe on the refractories and special materials are required. The proper solution to the bolt heading operations, however, requires the heating operation which will enable these pieces to be fed continuously. A modern bolt heading machine

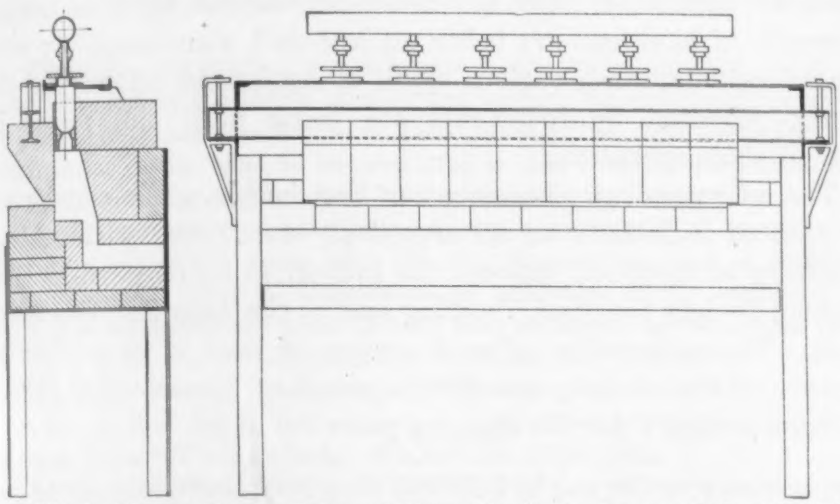


Fig. 7—Diagram Showing System of Firing Directly Against the Work as Used in a Bolt-Heading Forge.

will handle 120 standard ¾ inch bolts per minute. When using slot forges, a crew of four men is required for the heating of the work, one man at the machine, one bringing the material to the forges and two to handle the work between forges and machine. An automatic forge which handles the material mechanically from a hopper through the forge to the machine operator will eliminate the work of two of these men, the resultant savings entirely eclipse ing costs of fuel.

Conclusions

In summarizing, we realize that the heat treating furnace developments began only 20 years ago. If this advance is not rated as surprising at least it can be considered as creditable even when compared to its speedy contemporaries in the automotive industry.

Further development involves the combined efforts of many factors; refractories, temperature controls, feed mechanisms, fuels, atmospheres, alloys, methods of combustion and metallurgy and

numerous subdivisions of each of these. In other words, further progress from now on calls for the advancement of science and not merely the invention of new forms of equipment. The fact that gas has been found well endowed as a metallurgical fuel merely serves to place upon the shoulders of the gas industry a responsibility of co-operation with the metallurgical industries.

One evidence of the appreciation of this responsibility is the metallurgical research program which the American Gas Association has instituted. The metallurgical research facilities, at the University of Michigan are being utilized and, simultaneously with these scientific studies, various types of equipment embodying the greatest potential improvements are being built and tested in practical shop operation.

The advancement of science can best be brought about by cooperation of industries on an organized basis. Surely there is a community of interests between the industries represented by The American Society for Steel Treating and by the American Gas Association. The cooperation of such groups at least gives reasonable assurance of the continuance of this period of "Accelerated Scientific Development" for the ensuing year.

DISCUSSION

Written Discussion: By A. M. Apmann of the Consolidated Gas Co. of New York.

The introduction of modern furnace equipment has done more than merely supplant old rule of thumb methods by proper scientific laws for heat treating. It has continually and can even more so be used to clean up that very necessary and usual eyesore, the heat treating department.

About eight months ago one of our customers installed a battery of high pressure gas-fired furnaces automatically controlled. They replaced a group of oil-fired furnaces using a very high grade and, consequently, expensive oil. A fuel guarantee was made and a time cycle planned which shortened the operation 30 per cent. But still the expected fuel costs were over three times as great as the past records showed. The furnaces were built as modern furnaces should be; high grade, refractory, sufficient insulation, proper burner distribution and attractive substantial casings. The results obtained from this installation, which is very much like carburizing but at a higher temperature; were salutatory. Because of the heat distribution and insulation, the time cycle was reduced 40 per cent more than anticipated with a better quality product. Because of the usual conservative estimates of fuel consumption this was almost 30 per cent under the guarantee. Because of the close tie up between the customer and ourselves, six men out of nine were eliminated.

Credit here is only due to the furnaces indirectly as the customer designed and built the charging device.

The attractive appearance of the furnaces, however, whetted the imagination of the customer. The heat treating room was thoroughly cleaned and whitewashed. The sturdy aluminum-painted casings are set now in an ever clean atmosphere. Perfect combustion has eliminated smoke. Oil drippings are gone. The insulation has improved working conditions until they are practically ideal. But best of all, the improvement in morale is most marked. Instead of the heat treating job being something to be shunned, it is now a mark of distinction and the operators rival as far as practical those in bakeries and dairies.

That price difference has disappeared. Absence of rejected goods eliminated that, and it can surely be said that modern furnace design is not only profitable from the standpoint of bank balance but also from the human standpoint. We are glad to be associated in this work as the manufacturers and distributors of the ideal fuel of the present and future—Gas.

P. C. OSTERMAN: I have listened with a great deal of interest to Mr. Hepburn's talk and I agree with him that the advancement of science can best be brought about by cooperation of industries on an organized basis, but I presume he did not mean to have that statement on the second page of the paper taken too literally in which he thinks the developments in this field might best be recorded by a newspaper reporter. I am inclined to think that, after all, whether they be tedious tactics or otherwise, a trained engineer would be much the better one to make such surveys and reports.

In this connection, I am quite sure most of you will be somewhat puzzled by the statement referring to box carburizing, on the eighth page of his paper, "Gross efficiency of more than 40 per cent is maintained." I do not know just what gross efficiency might mean, but I think we would all be much more interested in the net efficiency and what would be the several items included in arriving at the net efficiency.

So far as carburizing is concerned, he points out that it is receiving considerable study as to the way of reducing the time required for surface carburization to take place with the present pots and compound. I might mention that it is also receiving detailed study from the viewpoint of ascertaining what results can be secured using commercially available gases supplied in cylinders for this work.

Thus far, results which have been secured point to a very satisfactory conclusion which will permit carburizing by gas in localities where either gas is not now available or the gas which is available is unsuited for some reason for the process in question.

Surface hardening in another guise, that is, nitrogenizing, is also receiving some considerable study by metallurgists, steel companies and furnace builders. This new process, patents covering which, it might be mentioned, are held by A. W. Machlet, not only as to the process but also as to the equipment in which the process may be conducted, gives promise of supplying a casehardened steel which will be superior to the case secured by carburizing for many purposes. This process, like the process of carburizing with com-

pressed gas supplied in cylinders, is still more or less in its infancy and considerably more research and testing work will be required before many claims can be made for it. Present developments point to the fact that with it an extremely hard case which does not require quenching in order to secure maximum hardness and which may be secured at comparatively low temperatures when necessary, is secured. This case, furthermore, is rust-proof, which makes it of unusual value for parts such as hardware, pump parts, etc.

To refer again to retort carburizing using gas as the carburizing agent, this process offers possibilities in stil further reducing the low carburizing cost over that as it now obtains in these machines. To cite one instance which gives the results of a survey recently made, the cost of carburizing rollers in a standard 600-pound capacity rotary carburizing machine was $9.90 per thousand pounds of work. This cost is based on operating twenty-four hours per day with labor at $1.40 per hour for operator and helper and gas at 67.6 cents per thousand cubic feet. This cost is about one-third of the cost as obtained in an oil-fired box type oven furnace of equal capacity which was formerly used and in which the final cost for carburizing was $27.63 per thousand pounds. In these comparisons everything is included, that is, interest on the investment and depreciation of equipment in both cases, the fuel and the labor, etc.

Mr. Hepburn has pointed his remarks particularly toward the utilization of gas on large-size equipment. We are certain that in so doing he felt that the case for gas in the main has been proven for smaller applications. However, one instance of comparative results may be of interest.

At the plant of an instrument manufacutrer in Chicago an electric furnace was installed for heat treating magnets. The gas company induced this manufacturer to install an oven furnace in order to check up and prove to their own satisfaction which equipment was most satisfactory. In each case the available heating space was approximately 18 inches wide by 36 inches deep, the cost of equipment being approximately the same. Both furnaces were of latest construction, with insulation and other features used in modern furnace design. The electric furnace heated 433½ pounds of work in an eight-hour day. One and one-half hours were required to bring the furnace up to temperature. The gas-fired oven heated 1080 pounds of work in a day and the time required to bring the furnace to temperature after the preceding day's operation was the same. With gas at 85 cents per thousand, the cost per pound for heating was $0.00266, whereas the cost of heating in the electric furnace, with power at 1½ cents per kilowatt, was $0.0052. In other words, the gas-fired furnace heated between two and two and one-half times as much work as the electric furnace, at approximately one-half the cost. One workman was engaged at each furnace, so that in the case of the electric furnace, the labor cost was in excess of twice the labor cost on the gas-fired furnace. The product in each case was equally satisfactory.

In referring to forging, I quite agree with Mr. Hepburn that the essential point is to see that the material is heated quite thoroughly through, and a great many savings could be made if that were more carefully followed. It seems that considerable study could be given to the size of hammer em-

ployed in drop forging. It is my opinion that, in general, too small a hammer is employed and that then leads the operator to overheat his work and when the work is removed, there is a great deal of scale, and that scale, of course, is injurious to the dies and so on. If a heavier hammer were employed, temperatures two, three or four hundred degrees lower than often are used now could be used, with a resultant saving in fuel consumption and in wear and tear on the furnace lining, wear and tear on the dies, and a cleaner product could be secured.

It is often said that there is a place for every fuel and source of heat energy and that with it the best and most uniform product will be secured at the lowest cost. In some cases gas may not be chosen, but in most instances, basing our statement on many years of observation and experience, gas will prove most satisfactory.

Educational Section

These Articles Have Been Selected Primarily For Their Educational And Informational Character As Distinguished From Reports Of Investigations And Research

FACTS AND PRINCIPLES CONCERNING STEEL AND HEAT TREATMENT—Part XVI[1]

By H. B. Knowlton

Abstract

This is the first of a series of articles on the subject of case carburizing and case hardening. In this article it is attempted to explain briefly what case hardening is, to review the history of case hardening; to give the reasons for case hardening today and to discuss the selection of steels suitable for case hardening. The following points are brought out.

The case hardening process consists in raising the carbon content of the surface of low carbon steel and giving heat treatments which will harden the case and strengthen and toughen the core. It is one of the oldest of all of the heat treating processes and is still valuable today as by this method a combination of strength, toughness and surface hardness can be produced which can not be equalled by any other method. For high quality case hardening it is necessary to use a well made, clean, low carbon steel. Superior results may be obtained with the use of certain alloy steels. Specifications are given for case hardening steels and normal and abnormal steels are briefly discussed.

Case Hardening

CASE hardening is the process of hardening the surface of low carbon steel. As low carbon steel cannot be hardened to any great degree, the first step consists in raising the carbon content in the outer layer of the steel to a point where hardening is possi-

[1]This is the sixteenth installment of this series of articles by H. B. Knowlton. The several installments which have already appeared in Transactions are as follows: March, June and October, 1925; January, April, May, June, August, October, December, 1926; March, May, July, September, November, 1927.

The author, H. B. Knowlton, member of the Fort Wayne Group of the Society, is metallurgist of the Fort Wayne Works, International Harvester Company, Fort Wayne, Ind.

ble. This is done by heating the steel in contact with some material (either solid, liquid, or gas) which will impart carbon to the steel. As the carbon is absorbed by the surface of the steel, a layer is formed at the surface which is high in carbon. This high carbon layer is termed the "case". The explanation of the use of the term is simple enough. As the high carbon layer at the surface of the steel is harder and stronger than the material in the center it is similar to the more familiar shipping cases which are frequently stronger than the materials which are packed in the cases.

The process of increasing the carbon content in the outer layer of the steel is known as "carburizing". It is sometimes also called "carbonizing" although in the strictest sense this is a missusage of the word. The process of converting wood into charcoal or coal into coke is properly termed carbonizing. This consists in driving out of the wood or coal all of the constituents except carbon. The process of adding carbon to the steel is really the reverse and should be called carburizing. Some writers use the term "cementation" in the place of carburizing. The carbon as it appears in steel is called "cementite" by most metallurgists.

After the case has been produced by carburizing, one or more heat treatments are given which harden the case and produce the desired strength of both the case and the core. (All of the steel beneath the case or high carbon layer is called the "core"). The quenching treatments are frequently although not always followed by tempering to relieve strains and increase the toughness. While it may be technically correct to apply the term "case hardening" only to the quenching treatment which produces the hardness of the case, it is common practice to use the term case hardening to include the entire process of carburizing, and heat treating after carburizing.

History of Case Hardening

Case hardening is probably the oldest of all of the heat treating processes. The reduction of iron from the ore is centuries older than any written history. The process of hardening and tempering of steel was known at least 900 B. C. The most ancient iron was undoubtedly produced by heating the ore on a bed of burning charcoal. The iron thus produced was similar to our modern wrought iron. It contained little or no carbon and could not be hardened. However if the iron was left in contact with the hot charcoal for

much longer than the usual time the surface would gradually absorb carbon. Thus a high carbon layer would be formed at the surface which would harden when quenched in water from a high temperature. It is entirely probable that the first steel which was capable of being hardened and tempered was produced by accidently leaving the iron in the bed of burning charcoal for an unusually long time. This process was the ancient ancestor of our modern case hardening. The hardening of steel made by some such a method, by quenching the hot steel in water or in the body of a man or animal was known for centuries before the dawn of written history.

While the history of the development of iron and steel is rather obscured by the fact that all processes were kept secret or were handed down by word of mouth only until recent times, it seems probable that the carburizing of finished articles such as swords and daggers was practiced by the ancients and persisted through the Middle Ages. Giolitti[1] states that certainly the process of surface carburizing was known in the sixteenth century. The processes then employed consisted in heating iron in contact with a carburizing powder consisting of carbon mixed with some organic material. He also mentions two references to the carburizing of iron by immersing in molten cast iron. This also took place during the sixteenth century.

In the seventeenth and eighteenth centuries the manufacture of high carbon steel by heating wrought iron bars in contact with charcoal to a temperature below the melting point until the bars were carburized more or less all the way through, became quite important. This was known as the "blister" method due to the blistered appearance of the surface of the bars at the end of the process. In this method wrought iron bars about ½ to ¾ inch thick are heated in wood charcoal to a temperature of about 1900 degrees Fahr. for about a week or 10 days. Since 1740 most of the high carbon steel thus made has been further refined by melting in crucibles after carburizing. The blister method is of interest from a historical standpoint, but due to the fact that it is such a slow laborious method, it has been practically replaced by faster and cheaper methods within the past century.

Object of Case Hardening

During the ancient and medieval times case hardening was

[1]Cementation of Iron and Steel.

probably practiced because it was the only known way of producing a steel which could be hardened and tempered. The question is sometimes raised as to whether such an old method has any place in modern heat treatment. This question can probably be answered in the affirmative. So far as we now know, certain results can be produced better by case hardening than by any other method.

The following may be given as the most common objectives for case hardening:

1. To produce the maximum surface hardness combined with the maximum toughness.
2. To produce a surface hardness as cheaply as possible.
3. To produce the desired color on the surface of the steel.

Of these the first objective is by far the most important. When a low carbon steel is properly case hardened the surface becomes as hard as hardened tool steel. At the same time the core being low carbon steel, is soft and tough. Thus a combination of strength, toughness and surface hardness is produced which is very desirable for certain parts.

There has been a tendency in some quarters to say that case hardening should be discarded and a "better grade" of steel be substituted. By this is usually meant that a properly heat treated medium carbon alloy steel is substituted for a low carbon case hardened steel. It is true that medium carbon alloy steel is superior to some of the cheapest forms of low carbon steel. However there are special alloy steels on the market which are designed particularly for case hardening. In fact one of the most expensive steels used in automotive construction is a low carbon 5 per cent nickel steel which is used almost exclusively for case hardening. When the proper steel and the proper method of case hardening are employed, results can be produced which cannot be duplicated by any other method.

In bearing out this statement reference might be made to the experience of a certain large automotive concern which manufactures a complete line of pleasure cars, busses and trucks. Several years ago it was reported that they had discontinued the practice of case hardening transmission gears. Instead the gears were made of medium carbon alloy steel. The heat treatment consisted in normalizing followed by heating to above the upper critical point quenching in oil and finally drawing or tempering. This worked

out very well on the pleasure car transmissions, but it was found that the transmissions on trucks and busses used in mountainous or sandy country, did not stand up as well as the transmissions having case hardened gears. Trucks which were operated under those conditions had to run in gear a large part of the time and were required to pull heavy loads. The teeth of the medium carbon alloy steel gears were not hard enough and strong enough to withstand these extreme conditions of service. It became necessary either to change the design or to return to low carbon alloy steel case hardened gears. The latter course was chosen according to the report.

Another interesting instance showing the value of case hardened alloy steel was reported during the war. In the manufacture of a certain airplane a great deal of trouble was experienced with wrist pins (or piston pins). Either they were too soft and wore until they became loose, or they were too hard and broke. A number of medium carbon alloy steels were tried without much success. Of course it would have been possible to change the design and make the wrist pins heavier. This would have meant increasing the weight of a part having a reciprocating motion (that part which moves back and forth). In airplane design it is desirable to keep the weight of reciprocating parts as low as possible. It requires energy to stop a piston at the end of its stroke and reverse the direction of the motion. Consequently increasing the weight of piston pins means a reduction of horse power. It was reported that the use of case hardened alloy steel pins was a successful answer to the problem. The pins used were of the hollow type and were hardened on the outside only.

These are two of many examples which might be given showing the value of case hardening when applied to certain parts. Of course there are many parts for which case hardening is not desirable. Case hardening has been found advantageous when applied to balls, rolls and races of bearings, gears which must withstand heavy tooth pressures, cam shafts, wrist pins and in general to all parts which require the maximum surface hardness and the maximum toughness.

Another class of parts which are usually case hardened is composed of screws, nuts, bolts and other small parts which require a ''skin'' hardness. That is the surface must be hard but the hardened layer must be very thin or there will be danger of the part

being broken. Such parts are usually hardened by the cyanide process. In this method the steel is either heated in melted cyanide or else is heated and sprinkled with powdered cyanide and then heated again. In the latter case the cyanide melts and clings to the steel so that both cases are really heating in melted cyanide. After heating, the steel is quenched in water or in oil. This method produces a very thin hard case, and will be discussed more in detail later.

Case hardening is looked on in some places as a cheap substitute for the use of hardened tool steel. There are some parts which require a hard surface but which do not require much strength or toughness. Any material having a hard surface would be satisfactory for such parts. In these cases it is often customary to employ a low carbon "machine steel" which is easily machined and then produce the hardness by case hardening. This is often cheaper than making the parts of the more expensive and less readily machinable tool steel. This however is not the most important branch of case hardening.

In some cases it is desired to produce a mottled colored surface as well as hardness. This is accomplished by heating the steel to comparatively low carburizing temperatures in contact with certain mixtures of bone, leather, charcoal and chemicals. Special methods of quenching may also be needed. From a metallurgical standpoint this method does not produce a very high grade of case hardened articles. Consequently no detailed discussion of the method will be given.

Steel For Case Hardening

The first and one of the most important steps in the case hardening process is the selection of a suitable steel. What constitutes a suitable steel depends upon the parts that are to be made. If the parts in question require no strength and toughness and if freedom from soft spots is unimportant, the cheapest kind of low carbon "machine steel", "screw stock" or "cold-rolled" may be employed. Unfortunately in some quarters these are the only case hardening steels that are known. Really high quality case hardening cannot be produced when such steels are used. When it is desired to produce a combination of maximum surface hardness and maximum strength and toughness certain special steels must be employed.

One of the most common specifications for a case hardening steel is that the carbon content be below 0.25 per cent. Some specifications demand that the carbon content be below 0.20 per cent. These specifications are perfectly sound as far as they go. In general the lower the carbon content (in any given type of steel), the greater will be the toughness produced by any given heat treatment. That is if two steels are of the same composition except for the carbon content and they are given the same heat treatment, the one with the lower carbon content will be the tougher. It should be mentioned, however, that for certain particular parts steel with carbon as high as 0.30-0.35 per cent have been successfully case hardened. The heat treatment of case hardened parts made of steel higher than 0.25 per cent carbon is rather difficult due to the fact that the core may be hardened to some extent unless the final quenching temperature is controlled very accurately.

The low carbon content is not the only specification which is necessary if high quality case hardening is to be done. For parts which do not require much strength or toughness it may be permissible to use steels described as "cold-rolled", "machine steel", "screw stock", etc. Such terms describe steels which have a low carbon content and which are readily machinable but which may have no other virtues. The cheapest, dirtiest grades of steel may be sold as machine steel. High quality case hardening is impossible when such steels are employed.

The following instance illustrates a type of case hardening failure which is due to the use of a dirty steel. Early in the development of the automobile a certain manufacturer specified Bessemer screw stock for nearly all bolts even including the spring bolts and steering spindle or king bolts. At first these bolts were used in the soft condition but as they wore badly it was decided to case harden them. Fortunately none of the case hardened king bolts ever left the factory. About 25 per cent of the first batch manufactured were broken after case hardening while they were being straightened preparatory to grinding. Naturally the rest of the bolts were scrapped and the steel specification was changed.

Both plain carbon and alloy steels of low carbon content are successfully used in case hardening. Let us first describe a plain carbon steel which is suitable for high quality case hardening. The same remarks will apply equally well to the alloy case hardening

steels, the only difference being that the latter contain one or more alloying elements.

The first requirement for any good case hardening steel is that it must be clean and sound; that is it must be commercially free from oxides, slag, and other harmful impurities, and similarly must be free from such physical defects as seams, pipes etc. The steel must be well made. In general, acid Bessemer steels (which are the only kind of Bessemer steels made in this country) are not suitable for case hardening. Open-hearth and electric steels of low carbon contents may or may not be suitable depending upon how well they are made.

The Society of Automotive Engineers gives the following specifications for plain carbon case hardening steels.

Steel Specification	1010	1015	1020
	Per Cent	Per Cent	Per Cent
Carbon	0.05-0.15	0.10-0.20	0.15-0.20
Manganese	0.30-0.60	0.30-0.60	0.30-0.60
Phosphorus	0.045 max.	0.045 max.	0.045 max.
Sulphur	0.05 max.	0.05 max.	0.05 max.

It will be noted that the specifications are identical except for the carbon content. The S. A. E. 1015 and 1020 steels are probably the most commonly used. It may be well to discuss briefly the effect of each of the elements above mentioned.

Manganese

Manganese tends to increase the strength and the hardening power of the steel but to decrease its toughness. It is common practice to hold down the manganese content of high carbon steels. In medium carbon steels a manganese content of 0.80 per cent is usually allowed. As the outer layer of a case hardening steel is high in carbon after carburizing, many engineers prefer to specify the manganese below 0.60 per cent. A high manganese content also means a lowering of the critical points of both core and case and consequently a lowering of the proper quenching temperatures. If a steel containing 1.00 to 1.25 per cent manganese is given the same carburizing and quenching treatments usually employed for low manganese steels the case will be made brittle and even the core may be hardened to some extent. On the other hand this same steel may yield very good results if the proper case hardening treatment is employed. On the other hand a very low manganese steel

(i. e., one containing less than 0.30 per cent manganese) might arouse suspicion. Manganese is added to steel as a cleaner and to take care of the sulphur present. An exceptionally low manganese steel might be a poorly made steel.

Phosphorus

It is commonly conceded that phosphorus is an objectionable impurity and should be held as low as possible. Steels which are high in phosphorus content are likely to be brittle. One of the principal objections to Bessemer screw stock is the allowance of 0.09 to 0.13 per cent for the phosphorus content. Even the open-hearth screw stocks are likely to contain more than 0.045 per cent of phosphorus.

Sulphur

The effect of sulphur is somewhat under dispute. If the manganese content is very low and the sulphur is found combined with the iron the steel will be brittle. Many engineers consider sulphur as an objectionable impurity even when the manganese content is high enough to assure that the sulphur will be present in the less harmful form of manganese sulphide. On the other hand some claim that sulphur up to 0.10 per cent when present as manganese sulphide is not harmful in a well-made steel. There is at least one steel on the market which is highly recommended by some for case hardening which is high in both sulphur and manganese contents.

Normality

Besides meeting the specifications thus far given, it is generally agreed that a good case hardening steel should have a certain degree of "normality". It will not be attempted in this article to give a detailed discussion as to what a normal steel is. This may be taken up at a later time. Many hardeners have discovered that certain lots of low carbon steel do not respond properly to the usual case hardening treatments. Trouble is experienced with soft spots and with lack of grain refinement of case or core or both. Sometimes changing the quenching temperatures or quenching speeds will produce satisfactory results. It is often true that no difference can be found in the chemical analysis or the microstructure between the steels which perform properly and those which do not.

Several years ago Messrs. McQuaid and Ehn attempted to ascertain the cause of these differences in performance. They discovered that there was a difference between the microstructure of different steels after carburizing and slow cooling, in spite of the fact that the chemical analysis and microstructure seemed to be the same before carburizing. Furthermore they proved that there was a definite relation between the microstructure of the steel after carburizing and slow cooling and the way that the steel would perform during the hardening treatments. Steels which after the usual quenching treatments had good grain refinement and a uniform surface hardness, they described as "normal", while steels which yielded soft spots and coarse grain after the usual treatments were termed "abnormal". After making these studies they purchased all carburizing steels on the basis of their appearance under the microscope after carburizing at a certain temperature and cooling slowly.

Unfortunately it is not possible to draw a sharp line of distinction between the normal and the abnormal steels. McQuaid and Ehn selected a series of steel specimens whose structures varied all the way from the extremely normal to the extremely abnormal. It has also been learned that the structure also depends upon the alloying elements if any which are present in the steel.

The McQuaid-Ehn test still has its proponents and opponents. There has been some difference in opinion with regard to the interpretation of the results. At least two of the largest producers of alloy carburizing steels and many of the largest consumers have adopted the test and believe that it has merit. When used properly in conjunction with other tests the writer would highly recommend the test.

Alloy Steels for Carburizing

When it is necessary to product the best possible combination of strength, toughness and surface hardness even the best plain carbon steel is not good enough. There are a number of low carbon alloy steels on the market which are used in the manufacture of case hardened automotive parts. Gears for transmissions and differentials, if case hardened, are made of low carbon alloy steel. Balls, rollers, and races for anti-friction bearings, spindle bolts, shackle bolts, and many other important parts are frequently made of such steels.

In general it may be said that the strength and toughness of the cores of case hardened alloy steels is greater than that of the corresponding plain carbon steels. Each of the alloying elements has its own functions. As nickel alloys with the ferrite it increases the strength and toughness and lowers the critical point and, consequently, the quenching temperature. It does not increase the hardening power and it is inclined to decrease the speed of carburizing. Chromium on the other hand combines with the carbon and increases the hardening power and the strength. Manganese increases the hardening power and lowers the critical point. Chromium-vanadium steels require higher quenching temperatures but have increased strength. A fairly wide range of quenching temperatures is claimed for the nickel-molybdenum steel. The 5 per cent nickel steel is one of the strongest steels used for case hardening. It has sometimes proved satisfactory for parts which must withstand extremely heavy loads and for which other alloy steels have been found unsatisfactory. On the other hand this is an expensive steel and its use is not justified for most case hardened parts. In general many alloy steels may be satisfactorily hardened in oil. Also it is frequently found that the alloy steels harden more uniformly.

The selection of the steel for case hardening depends upon the part which is to be made and the service which it must withstand. It is sometimes a problem whether to increase the size of the part or to use a stronger steel. In the case of airplane parts it is often necessary to obtain the maximum strength and toughness in proportion to the weight. This may mean the use of expensive steels and heat treatments. In other cases where size and weight is not so important it may be cheaper to make the design heavier and use somewhat cheaper steels and simpler heat treatments.

The following table gives the chemical composition of some of the alloy steels commonly used for case hardening.

Finish of Steel

One very important point which is frequently overlooked is the finish of the steel to be case hardened. A good clean machined surface is necessary if good case hardening is to be produced. Efforts to case harden the rolled surface of cold-rolled steels usually result in the production of soft spots. Seamless drawn tubing usually

Table Showing Chemical Composition of Steels Commonly Used for Case Hardening

Classification	Plain Carbon	Low Nickel	Low Nickel	3 Per Cent Nickel	5 Per Cent Nickel	Nickel-Chromium	Nickel-Chromium	Nickel-Chromium	Nickel-Chromium	Nickel-Molyb-denum	Chromium	Chromium-Vanadium	Manganese
Specific'n No.	1015	2015	2115	2315	2512	3115	3215	3312	3415	4615	5120	6120	....
Carbon	Per Cent 0.10-0.20	Per Cent 0.10-0.20	Per Cent 0.10-0.20	Per Cent 0.10-0.20	Per Cent 0.17 max.	Per Cent 0.10-0.20	Per Cent 0.10-0.20	Per Cent 0.17 max.	Per Cent 0.10-0.20	Per Cent 0.10 0.20	Per Cent 0.15-0.25	Per Cent 0.15-0.25	Per Cent 0.08-0.15
Manganese	0.30-0.60	0.30-0.60	0.30-0.60	0.30-0.60	0.30-0.60	0.30-0.60	0.30-0.60	0.30-0.60	0.30-0.60	0.30-0.60	0.30-0.60	0.50-0.80	1.20-1.50
Sulphur	0.05 max.	0.045 max.	0.045 max.	0.045 max.	0.045 max.	0.045 max.	0.040 max.	0.040 max.	0.040 max.	0.045 max.	0.045 max.	0.040 max.	0.040 max.
Phosphorus	0.045 max.	0.040 max.	0.040 max.	0.04 max.	0.04 max.	0.04 max.	0.04 max.	0.040 max.	0.040 max.	0.040 max.	0.040 max.	0.040 max.	0.040 max.
Nickel	....	0.40-0.60	1.25-1.75	3.25-3.75	4.75-5.25	1.00-1.50	1.50-2.00	3.25-3.75	2.75-3.25	1.50-2.00	....	....	....
Chromium	....	....	....	....	....	0.45-0.75	0.90-1.25	1.25-1.75	0.60-0.95	....	0.60-0.90	0.80-1.10	....
Vanadium	....	....	....	....	....	....	....	....	....	....	....	0.15 min.	....
Molybdenum	....	....	....	....	....	....	....	....	....	0.20-0.30	....	....	....

The plain carbon steel is the cheapest of these steels but does not develop as good physical properties as the alloy steels. The 2015 and 2115 low nickel steels are comparatively cheap and are slightly superior to plain carbon steel. The 3 per cent nickel 2315, low nickel-chromium 3115, nickel-molybdenum 4615, chromium 5120, chromium-vanadium 6120, and manganese steels are suitable for most parts requiring an alloy case hardening steel. The steels containing higher proportions of alloying elements are only recommended for special purposes.

In addition to these steels there should be mentioned the high sulphur high manganese, low phosphorus steel which is cheap, machines very well, and is superior to plain carbon steel, and the 1.00 per cent manganese 0.50 per cent chromium steel which compares favorably with the other low alloy steels.

Some specifications give the carbon content slightly different from that given in the above table, but never higher than 0.25 per cent maximum.

has score marks on the inside left by the drawing mandrel. These marks may be almost negligible or they may be very bad. While it may be possible to case harden some tubing without machining the hole free from score marks, efforts to case harden tubing frequently result in hardening cracks. When the hole is machined this danger is avoided. The same danger may be encountered in case hardening parts having badly rough-turned finish or having square shoulders. It should be needless to say that the surface should be free from scale, rust, dirt, oil and washing compounds before carburizing yet failures have been traced to all of these causes.

MACHINABILITY OF METALS

(Continued from Page 94)

machine all right, it begins to tear. I would like to have some light on the precise reason for the difference in those two, why one machines well and the other doesn't machine well.

O. W. Boston: Mr. Chairman, I can't see why he should ask me that question. (Laughter). The subject of machinability is interesting but not completely known. Sometimes cases come up where a particular metal seems to run contrary to all the laws for metals of its class. For instance, in Professor Benedict's work in drilling tests, he has found, as I remember it, the lowest Brinell number with the highest torque for S. A. E. 2315. Apparently that is an unusual type of steel, which may be comparable to the group of manganese steels, copper, wrought iron, and other metals which do not follow the general laws and do not, for various heat treatments or conditions, respond to the various tests as is expected. I am at a loss to explain why the different structures of the steel mentioned by Mr. Walker affects the machinability, but I am not surprised that it does. Such cases are necessary to convince us that there is much yet to be learned of metals and their reaction to cutting tools. The classical work of F. W. Taylor referred to above, and the many valuable contributions of Mr. Barth, in my opinion, are in a way limited in their practical value because of our limited knowledge of fundamentals.

In closing, I want to express my appreciation to those who have made the presentation of this paper possible, and to those who have taken part in the discussion. Thank you.

THE ENGINEERING INDEX

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Arrangements have been made with The American Society of Mechanical Engineers whereby the American Society for Steel Treating will be furnished each month with a specially prepared section of The Engineering Index. It is to include items descriptive of articles appearing in the current issues of the world's engineering and scientific press of particular interest to members of the American Society for Steel Treating. These items will be selected from the copy prepared for the annual volume of the Index published by the A. S. M. E.

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ALLOY STEELS

AUTOMOBILES, FOR. **Changes in Automobile Construction and Their Effect on the Use of Alloy Steels (Wandlungen im Automobilbau und ihr Einfluss auf die Verwendung legierter Stähle), H. Franz.** Motorwagen, vol. 30, no. 28, Oct. 10, 1927, pp. 607-612, 7 figs. Points out modifications in design and construction due to automobiles changing from sport to utility vehicles; characteristics of some special steels of German production, economy of using them in construction of automobile engines and gears and chances of substituting cheaper grades for them.

ALLOYS

HEAT OF SOLUTION. **Heat of Solution of Metals (Die Mischungswärme von Metallen). M. Kawakami.** Zeit. für anorganische u. allgemeine Chemie, vol. 167, no. 3-4, Nov. 1, 1927, pp. 345-363, 20 figs. Original determinations of increment in heat due to mixing of metals in liquid state; studies of numerous binary alloys of mercury, zinc, tin, lead, etc.

NOMENCLATURE. **On Alloys and Their Nomenclature.** Metal Industry (Lond.), vol. 31, no. 18, Nov. 4, 1927, pp. 407-408. Editorial remarks in which it is claimed that nomenclature of alloys is in condition of almost hopeless confusion; there is not even sound and unassailable definition of an alloy extant.

THERMAL EXPANSION. **Thermal Expansion of Nickel and Cobalt Alloys (Die thermische Ausdehnung der Kobalt-Nickel, Kobalt-Eisen und Eisen-Nickellegierungen), A. Schulze.** Physikalische Zeit., vol. 28, no. 20, Oct. 15, 1927, pp. 669-673, 8 figs. Chemical composition and expansion coefficients, between 20 and 100 deg. Cent., of binary alloys cobalt-nickel, cobalt-iron and iron-nickel; plotted graphs show remarkable discontinuity suggesting formations of intermediate crystalline structures.

ALUMINUM

ALLOTROPY. **Has Pure Aluminum an Allotropic Transformation (Hat Reinaluminium eine allotrope Umwandlung?), M. Hass.** Zeit. für Metallkunde, vol. 19, no. 10, Oct. 1927, pp. 404-406, 10 figs. Precise dilatometric observations which refute theoretical supposition as to allotropic transformation of aluminum at about 580 deg. Cent. See also English abstract in Metallurgist (Supp. to Engineer), Nov. 25, 1927, p. 175.

CASTING. **Observations on Casting Aluminum and Its Alloys, W. J. Clark.** Foundry, vol. 55, nos. 21 and 22, Nov. 1 and 15, 1927, pp. 847-849 and 891-893, 9 figs. Views of practical molder on his experience with aluminum and its alloys, importance of gating.

PROPERTIES. **Properties of Pure Aluminum (Les properiéts l'aluminium pur), L. Guillet.** Académie des Sciences—Comptes Rendus, vol. 185, no. 3, July 18, 1927, pp. 163-165. Properties of pure (99 per cent) aluminum differ little from usual commercial aluminums (99.0 to 99.5 per cent); resistivity is a little less.

ALUMINUM ALLOYS

COPPER ESTIMATION. **The Estimation of Copper in Aluminum Alloys, H. H. Shepherd.** Foundry Trade Jl., vol. 37, no. 586, Nov. 10, 1927, p. 104. Solutions required; standardization of sodium thiosulphate; determining copper content of sample.

Those members who are making a practice of clipping items for filing in their own filing system may obtain extra copies of the Engineering Index pages by addressing their request to the society headquarters.

CORROSION. Corrosion of Light Metals Used in Aircraft Construction (Korrosionserscheinungen und Korrosionsversuche an Leichtmetallen für den Flugbetrieb) E. Rackwitz. Korrosion u. Metallschutz, vol. 3, no. 8, Aug. 1927, pp. 171-177, 7 figs. Experimental determinations of loss of weight and strength due to corrosion of duralumin and similar light alloys when exposed to action of seawater.

HEAT CONDUCTIVITY. Heat Conductivity of Light Alloys (Sur la conductibilité thermique des alliages légers), C. Grard and J. Villey. Académie des Sciences—Comptes Rendus, vol. 185, no. 17, Oct. 24, 1927, pp. 856-858, 2 figs. Experimental study of aluminum-copper, and magnesium-copper-aluminum alloys, which may be used in engine construction, at various temperatures; calls attention to magnesium alloys.

LITHIUM DETERMINATION IN. Determination of Lithium in Scleron and Similar Aluminum Alloys (Die Bestimmung von Lithium in Scleronmetall und ähnlichen Aluminiumlegierungen, E. Schürmann and W. Bohm. Chemiker-Zeitung, vol. 51, nos. 70 and 72, Sept. 3 and 10, 1927, pp. 677-678 and 698-699. Describes method employed. See translated abstract in Chem. & Industry, vol. 46, no. 43, Oct. 28, 1927, p. 818.

SAND-CAST. The Strasser Sand-Cast Aluminum-Cast Iron Alloy, Alneon [Ueber die Strasserschen Aluminium-Gusslegierungen (Alneon)], M. von Schwarz. Zeit. für Metallkunde, vol. 19, no. 10, Oct. 1927, pp. 390-395, 9 figs. Mechanical and physical properties, microstructure of high strength aluminum zinc alloy, effect of casting skin.

ALUMINUM BRONZE

PROPERTIES. Aluminum Bronzes (Les bronzes d'aluminium). Revue Industrielle, vol. 57, no. 2218, Sept. 1927, pp. 437-443, 7 figs., and translated abstract in Am. Mach., vol. 67, no. 19, Nov. 10, 1927, p. 749. Generally aluminum bronzes used in industry have from 7 to 12 per cent of aluminum; alloy is used either cast or shaped; aluminum bronzes can be heat treated somewhat like steel; within very appreciable range of temperatures mechanical features remain practically unaffected; density, resistance to corrosion, thermal conductivity, and other properties.

BEARING METALS

CASTING. Effect of Casting Temperature on Properties of Bearing Metals (Der Einfluss der Giesstemperatur auf die Laufeigenschaften von Lagermetall), H. Graefe. Maschinenbau, vol. 6, no. 20, Oct. 20, 1927, pp. 1001-1005, 23 figs. Experimental study done at testing laboratory of Siemens-Schuckert-Werke A. G., showing that wearing quality of white metal bearings depends on grain size of metal.

SELECTION. Choosing White Bearing Metals, E. R. Thews. Am. Mach., vol. 67, no. 20, Nov. 17, 1927, pp. 759-760. Great number of combinations possible in white bearing-metal alloys makes it desirable for designer and shop man to have clear understanding of effects of each element entering into alloy on final bearing qualities of metal to be selected for bearing.

BERYLLIUM

PRODUCTION, AND USES. Production and Uses of Beryllium (Herstellung und Verwendung des Leichtmetalles Beryllium), K. Illig. Zeit. für angewandte Chemie, vol. 40, no. 42, Oct. 20, 1927, pp. 1160-1163. Discovery and development of production methods, properties used in X-ray apparatus and in alloys of steel, copper, nickel, etc., upon which it has a great hardening effect; prices and market.

PROPERTIES. Beryllium (Beryllium, ein neues Leichtmetall der Technik), J. Becker. Zeit. für Elektrochemie, vol. 33, no. 5, May 1927, pp. 181-185, 1 fig. Stock-Goldschmidt process of making beryllium has already greatly lowered cost of metal, and it may be expected that as supply increases demand will increase accordingly, so that large-scale production and use will ultimately be feasible; as a lighter metal than aluminum, beryllium has some important properties from technical standpoint; it is harder than glass, has a very high melting point and is malleable.

BLAST FURNACES

COKE BEHAVIOR IN. Behavior of Coke in the Blast Furnace, T. L. Joseph. Am. Iron & Steel Inst.—Advance paper, for mtg., Oct. 28, 1927, 24 pp., 3 figs. It is believed that failure to define properties of coke clearly is partly responsible for retarding progress in correlating coke properties and furnace practice; One important function of coke is to decrease resistance of charge to gas flow; this is more satisfactorily performed by large pieces of coke of low density which will retain their size until reaching tuyeres; physical properties of coke bear important relation to physical and mechanical problems presented by blast-furnace process. See translated abstract with discussion in Iron Age vol. 120, no. 19, Nov. 10, 1927, pp. 1300-1302.

DIRECT REDUCTION IN. Calculation of Carbon or Gasified Oxygen Consumed in Process of Direct Reduction in the Blast Furnace (Zur Berechnung der durch direkte Reduktion im Hochofen verbrauchten Kohlenstoffs bzw. vergasten Sauerstoffs), E. Maurer. Archiv für Eisenhüttenwesen, vol. 1, no. 5, 1927, pp. 331-337. Discusses calculating methods of Gruner, Wedding-Richards, Wüst, Mathesius, Osann and Thaler; shows that these formulas, with exception of that of Thaler, can be combined or made to agree with one another and, based on examples author shows why these formulas give different results and under what conditions similar results can be obtained.

DRYING OF BLAST. Silica Gel. Chem. & Industry, vol. 46, no. 40, Oct. 7, 1927, pp. 902-904, 7 figs. It is found that silica gel can absorb at atmospheric temperature from 30 to 50 per cent of its weight of water, and that by raising temperature, done by passing waste blast-furnace gas at 640 deg. Fahr., this water can be driven off, leaving reactivated gel ready for another cycle.

BLAST FURNACES

EXCESS-GAS GENERATION. The Use of the Blast Furnace as a Gas Producer, R. Franchot. Fuels & Furnaces, vol. 5, no. 11, Nov. 1927, pp. 1451-1454. Discusses generation of excess gas in blast furnace; its

use; provision for, and effect of, excess gas outlet on blast-furnace operation.

GREAT BRITAIN. Blast Furnaces of the United Kingdom. Foundry Trade Jl., vol. 37, no. 585, Nov. 3, 1927, loose supp. plate. Tabular data on furnaces built and in blast.

HEAT BALANCE. The Appraisal of Blast-Furnace Heat Balance according to Blast-Furnace-Gas Analysis and Blast Capacity (Die Beurteilung der Stoff- und Wärmebilanz des Hochofens nach der Gichtgasanalyse und der Windmenge), H. Bansen. Archiv für das Eisenhüttenwesen, vol. 1, no. 4, Oct. 1927, pp. 245-266, 18 figs. Calculation of ballast substances in blast-furnace gas and change of working analysis into gas analysis; calculation of substance values from gas composition; characterization of different blast-furnace processes from gas analysis; calculation of required and available heat volumes and coke consumption for metallurgical purposes. See abstract in Stahl u. Eisen, vol. 47, no. 45, Nov. 10, 1927, pp. 1908-1909.

REDUCTION PROCESS. The Reduction of Manganese Oxide, Silicic Acid and Phosphoric Acid in the Blast Furnace (Ueber die Reduktion von Manganoxydul, Kieselsäure und phosphorsäure im Hochofen), H. H. Meyer. Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf, vol. 9, no. 18, 1927, paper no. 91, pp. 273-277. Reduction with carbon, hydrogen and carbon monoxide; influence of iron on beginning of reduction; determination of silicon concentration; formation of pig iron in blast furnace.

SHAFT, COMBUSTION TEMPERATURE. The Calculation of Combustion Temperature in Shaft Furnaces (Zur Berechnung der Verbrennungstemperatur in Schachtöfen), K. Mühlbradt. Stahl u. Eisen, vol. 47, no. 43, Oct. 27, 1927, pp. 1813-1816. It is shown that usual method of calculating initial temperatures, based on combustion condition and excess air, rests on false assumptions, as its basic principles are taken from gas-furnace technology, in which only gaseous phases enter into reaction, whereas in shaft furnace there is reaction between heterogenous phases; scheme is developed, based on combustion in gas producer, which characterizes influences bearing upon temperature in shaft furnace.

BRASS

INGOT MELTING. Some Practical Notes on the Manufacture of Brass Ingots or Strip, N. F. Fletcher. Metal Industry (Lond.), vol. 31, no. 19, Nov. 11, 1927, pp. 441-442. Describes methods whereby metals which form brass are melted and cast into ingots for subsequent rolling into strips. Paper read before Midland Section of Junior Instn. of Engrs.

YELLOWING. Influence of the Concentration of (Nitric) Acid on the Acid Consumption in the Yellowing of Brass (Ueber den Einfluss der Säurekonzentration auf den Säureverbrauch beim Gelbbrennen von Messing), E. Dorn. Zeit. für Metallkunde, vol. 19, no. 7, July 1927, pp. 280-281, 1 fig. In pickling brass with nitric acid alone to obtain a yellow finish, pickling bath becomes ineffective when acidity falls below 30 per cent; addition of sulphuric acid to bath decreases initial rate of attack on metal, but increases velocity of reaction towards end.

BRONZES

CELLULOSE BLEACHING LIQUORS, EFFECT OF. Behavior of Bronze in Cellulose Bleach Liquors (Das Verhalten von Bronze in Zellstoffbleichlauge), W. Heike and F. Westerholt. Zeit. für Metallkunde, vol. 19, no. 7, July 1927, pp. 285-287. Effect of tin and lead content and of annealing on bronze used in screw conveyor working in mixture of cellulose and bleach liquor (sodium hypochlorite); it appears that tin content alone has important bearing on corrosion of bronze by hypochlorite liquors, a high tin content evenly distributed giving most satisfactory results.

MANGANESE. Manganese Bronze Specifications. Metal Industry, (N. Y.), vol. 25, no. 11, Nov. 1927, pp. 449-451. U. S. government proposed master specification for manganese-bronze rods, bars, shapes and plates.

CABLES, ELECTRIC

STEEL-ALUMINUM. Strength Investigations for the Standardization of Steel-Aluminum Cables (Festigkeitsuntersuchungen zur Normung der Stahl-Aluminium-Seile), G. Berling and W. Rössler. Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, no. 293, 1927, 12 pp. Results of tests carried out by A. E. G., Felten & Guilleaume, and Siemens-Schuckert Works, under auspices of Soc. of German Elec. Engrs., involving sag calculation, and calculation of best cross-sectional dimensions.

GAS CARBURIZATION. Gas Carburization of Steel, R. G. Guthrie and O. Wozasek. Am. Soc. Steel Treating—Trans., vol. 12, no. 6, Dec. 1927, pp. 853-868 and (discussion) 868-870, 10 figs. Deals with use of so-called city or manufactured gas for carburizing medium and considers certain inconsistencies heretofore encountered in its use: (1) variation in depth and concentration of case from day to day; (2) what constituent in gas is responsible for carburization of steel; (3) mechanism of carburization; (4) factors affecting this mechanism; results show advantages to be gained from treatment of carburizing gas at furnace, and catalyzing steel in furnace at beginning of run.

CASE-HARDENING

NITRATION HARDENING. Case Hardening of Special Steels (Sur la nituration des aciers speciaux), L. Guillet. Académie des Sciences—Comptes Rendus, vol. 185, no. 17, Oct. 24, 1927, pp. 818-821. Reports experiments which showed that nitride case hardening of aluminum-chrominum-nickel steels causes "Krupp's" disease, i. e., about 80 per cent decrease in resilience, which may be suppressed almost entirely or in part by adding tungsten or molybdenum.

PROCESSES. Case Hardening Processes. Fuels & Furnaces, vol. 5, no. 11, Nov. 1927, pp. 1443-1444. Carburizing process may be roughly divided into two distinct operations: (1) carburization or impregnation of surface by which carbon content is sufficiently raised so as to produce steel capable of taking on very great surface hardness; (2) suitable heat treatment to develop properties of both case and core; complete operation produces very hard case and core with special property of non-brittleness; factors which must be considered in carburizing operation.

CAST IRON

AUTOMOBILE INDUSTRY. Gray Cast Iron in the Construction of Automobiles and Aircraft (Grauguss im Automobil- und Flugzeugbau), G. Meyersberg Giesserei, vol. 14, no. 43, Oct. 22, 1927, pp. 747-750. Discusses improvements in cast iron and properties which make its use in automobile and aircraft manufacture advisable.

BRONZE WELDING. How Modern Welders Use Bronze, W. O. Swift Acetylene Jl., vol. 29, no. 5, Nov. 1927, pp. 193-194 and 196. How bronze came into use for welding castings; correct method of using bronze filler; examples of high-strength bronze welds.

ELECTRICAL MACHINERY, FOR. The Use of Cast Iron and Cast Steel in the Construction of Electrical Machinery (Die Verwendung von Gusseisen und Stahlguss im Elektromaschinenbau), L. Schmid. Giesserei, vol. 14, nos. 43 and 44, Oct. 22 and 29, 1927, pp. 750-757 and 770-775, 31 figs. Discusses special requirements of gray-iron and steel castings used in construction of electric machines and steam turbines.

FARM MACHINERY. Gray and Malleable Cast Iron in the Construction of Farm Machinery (Ueber Grauguss und Schwarzguss als Konstruktionsmaterial für Erntemaschinen), H. Jungbluth. Giesserei, vol. 14, no. 46, Nov. 12, 1927, pp. 709-805, 16 figs. Investigates special properties of gray and malleable iron used in manufacture of agricultural implements, production of castings and defects.

GRAPHITE IN. Graphite in Gray Cast Iron (Der Graphit im grauen Gusseisen), P. Bardenheuer. Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf, vol. 9, no. 13, paper no. 86, pp. 215-225, 48 figs. partly on supp. plates. Significance of graphite in cast iron; theory of graphite separation; relation between crystallization of graphite and its form and distribution; influence of graphite formation on properties of gray cast iron; older and new methods of graphite separation.

HIGH-GRADE. Krupp's "Sternguss" Cast Iron (Ueber den Kruppschen Sternguss), P. Kleiber. Kruppsche Monatshefte, vol. 8, June-July 1927, pp. 109-117, 27 figs. Manufacture, composition, microstructure, and mechanical strength of low carbon cast iron produced by cupola method without treatment before or after melting.

HIGH-STRENGTH. Makes High Test Cast Iron, M. E. Greenhow. Foundry, vol. 55, no. 23, Dec. 1, 1927, pp. 919-920. Castings with varying sections require a close-grained, high-strength, wear-resisting iron which is obtained by nickel additions; gives results and data on method followed.

INDUSTRIAL USES. Cast Iron as Engineering Material (Gusseisen als Werkstoff), T. Geilenkirchen. Giesserei, vol. 14, no. 43, Oct. 22, 1927, pp. 721-724. Discusses development and importance of cast iron as engineering material for trade products and as basic material for iron-working industry.

PEARLITIC. Pearlitic Cast Iron for Heat Engines and Their Appurtenances (Perlitguss für wärmetechnische Zwecke), G. Meyersberg. Archiv. für Wärmewirtschaft, vol. 8, no. 11, Nov. 1927, pp. 340-341, 6 figs. Shows that mechanical properties of pearlitic iron, particularly its resistance to high temperatures, make it most suitable as construction material for thermo-technical purposes, such as high-pressure plants, internal-combustion engines, etc.

PHOSPHORUS, INFLUENCE OF. The Resistance to Wear of Cast Iron Containing Phosphorus (Ueber den Verschleisswiderstand des phosphorhaltigen Graugusses), E. Piwowarsky. Giesserei, vol. 14, no. 43, Oct. 22, 1927, pp. 743-747, 4 figs. Results of tests show that wear strength resistance increases with increasing phosphorus content; tests were carried out with two different testing devices, namely, Amsler and Spindel machine.

PROBLEMS. International Foundry Congress (Le Congres International de Fonderie). Fonderie Moderne, vol. 21, Oct. 10, 1927, pp. 399-411. Abstracts of papers on cast iron, molding sand, alloys and non-ferrous metals.

RAILWAY USES. Cast Iron as Railway Construction Material (Gusseisen als Werkstoff der Eisenbahnen), K. Sipp. Giesserei, vol. 14, no. 45, Nov. 5, 1927, pp. 781-784. Based on older and more recent specifications of German State Railway, requirements of castings employed in railway-machinery construction are critically considered.

REFINING. Metallography and Refining of Cast Iron (Die Metallographie und Veredlung des Gusseisens), A. Achenback. Giesserei, vol. 14, no. 43, Oct. 22, 1927, pp. 724-743, 47 figs. Discussion of theoretical principles and details of numerous processes for refining cast iron.

SPECIAL GRAY. Special Gray Iron for Diesel Engines (Veredelter Grauguss, besonders für Dieselmotoren), B. Schulz. Motorwagen, vol. 30, no. 29, Oct. 20, 1927, pp. 625-628, 4 figs. Composition and properties of special irons and iron alloys developed by large German and Swiss manufacturers (Krupp, Sulzer, etc.).

STRENGTH OF. The Strength of Cast Iron, J. E. Fletcher. Foundry Trade Jl., vol. 36, no. 570 and 571, July 21 and 28, 1927, pp. 69-72 and 89-92, 5 figs. Presents deflection in transverse tests; dominating influence of silicon and total carbon together, and importance of carbon and silicon proportions in (T. C. + Si) factor must have first attention when attempting to interpret analysis of cast iron in terms of its mechanical strength.

CASTING

CENTRIFUAL. Centrifual Castings for Locomotive Piston-Valve Bushings. Engineering, vol. 124, no. 3225, Nov. 4, 1927, pp. 580-581, 4 figs. Importance attached by locomotive engineers to centrifugal castings for piston-valve liners, is shown by fact that they are now frequently specified; process known as Spun-Sorbitic is new development of Hurst-Ball process; it enables casting, having relatively low silicon contents, ranging from 0.75 to 1.5 per cent; to be produced without incurring danger of chilled surfaces or hard spots; important feature of process is that casting is cooled from temperature immediately below solidification point by means of special type of wet-air blast; immediate effect of this special cooling treatment is to convert pearlite into sorbite.

DESIGN. Foundry Practice and the Design of Castings, T. Makomson. Foundry Trade Jl., vol. 37, no. 586, Nov. 1927, p. 110, 2 figs. Author cites directions in which design increased difficulty of foundryman; closest co-operation should exist between foundry and pattern shop, and a representative of foundry should give a lead with regard to general method that it was intended to follow when molding any given job.

COKE

MECHANICAL STRENGTH. The Mechanical Strength of Coke (Die mechanische Festigkeit des Kokes), G. Dörflinger. Stahl u. Eisen, vol. 47, no. 44, Nov. 3, 1927, pp. 1867-1871, 4 figs. Determination of its resistance to fracture and friction by means of so-called Micum drum; the ground and crushed coke is classified on screens, and measure of strength is shown by quantity of lumps remaining which are over 40 mm. in size, and also by quantity of fine breeze of 0 to 7 or 0 to 10 mm. formed by operation of drum.

METALLURGICAL. Properties of Metallurgical Coke, R. P. Hudson. Blast Furnace & Steel Plant, vol. 15, no. 11, Nov. 1927, pp. 526-527. Recital of properties and characteristics coke should possess in order that it may serve most efficiently as a fuel in blast furnace.

COPPER ALLOYS

ADNIC. Physical Properties of Adnic, W. B. Price. Min. & Met., vol. 8, no. 251, Nov. 1927, pp. 474-475, 2 figs. New corrosion and heat-resisting white-metal alloy, having composition of copper, 70 per cent; nickel, 29 per cent; tin, 1 per cent.

COPPER-ALUMINUM-MANGANESE. Constitution and Magnetic Properties of Alloys of Copper Aluminum and Manganese (Beitrag zur Kenntnis des Dreistoffsystems Kupfer-Aluminium-Mangan und seiner magnetischen Eigenschaften), W. Krings and W. Ostmann. Zeit. für anorganische u. allgemeine Chemie, vol. 163, no. 1-2, June 28, 1927, pp. 145-164, 5 figs. Study of Heusler alloys, which contain 12 to 13 per cent aluminum and about 20 to 30 per cent manganese.

HEAT TREATMENT. The Effect of Heat Treatment on Some Mechanical Properties of 88.7: 11: 0.3 Copper-Tin-Phosphorus Alloy, R. J. Anderson. Am. Metal Market, vol. 34, no. 223, Nov. 18, 1927, pp. 3-6, 15 figs. Study of effects of annealing at different temperatures (followed by air cooling) and of quenching from various temperatures on tensile properties and hardness of this alloy. Bibliography.

PHOSPHOR-COPPER. Phosphor-Copper. Foundry Trade Jl., vol. 37, no. 585, Nov. 3, 1927, p. 86. Claim is made that by method described, no loss of phosphorus is sustained and that a uniform phosphor-copper is produced with introduction of 15 per cent phosphorus.

CORROSION

ELECTROCHEMICAL PROBLEM, AS. Corrosion (Die Korrosion der Metalle als Elektrochemisches Problem), A. Thiel. Zeit. für Elektrochemie, vol. 33, no. 9 Sept. 1927, pp. 370-386 and (discussion) 387-388, 5 figs. New experiments are reported which are based on theory that corrosion is strictly electrochemical problem; results tend to confirm local element theory and to support diffusion theory as an auxiliary.

TESTING. Corrosion Detected by D. O. C. Test, H. J. Young. Oil & Gas Jl., vol. 26, no. 27, Nov. 24, 1927, pp. 146-148. Severe corrosion having occurred on pins and journals of crankshafts of two motorships it fell to author to ascertain cause and if possible to find remedy; he devised what he calls direct oil-corrosion test, performed by means of apparatus whereby warm oil is run continuously over warm steel, white metal, brass, copper, or any other metal. See also Mar. Engr. & Motorship Bldgr., vol. 50, no. 603, Nov. 1927, pp. 424-426, 5 figs.

THEORY OF. The Theory of Metallic Corrosion in the Light of Quantitative Measurements, G. D. Bengough, J. M. Stuart and A. R. Lee. Roy. Soc.—Proc., vol. 116, no. 774, Oct. 1, 1927, pp. 425-467, 11 figs. Object of research is discovery of a satisfactory way of measuring corrosion of metals in water and dilute salt solutions, and use of it to test adequacy of newer electrochemical theory of corrosion as applied to such media.

CRUCIBLES

REFRACTIVE. Refractive Crucible (Ein bei sehr hohen Temperaturen haltbarer Kohletiegel), M. K. Hoffmann. Zeit. für Elektrochemie, vol. 33, no. 5, May 1927, pp. 200-202. It has been found that heat resistance of carbon crucibles can be greatly improved by heating them in electric furnace with a colloidal solution of a carbide-forming oxide; treated crucibles will withstand temperature of more than 2000 deg. Cent. for a considerable time; silica treatment is recommended for all metals which will not react with SiC.

CUPOLAS

CHARGING. Automatic Charging of Cupolas, H. A. Jahraus. Iron Age, vol. 120, no. 20, Nov. 17, 1927, pp. 1363-1366, 2 figs. Push buttons and limit and time switches control operation; coke and limestone handled in simliar way at plant of Buick Motor Co.

Charging Coke by Machinery, F. L. Prentiss. Iron Age, vol. 120, no. 20, Nov. 17, 1927, pp. 1372-1373, 3 figs. Manual labor has been eliminated to vast extent in handling raw material to cupolas in new continuous gray-iron foundry of Buick Motor Co., Flint, Mich.

DESIGN AND OPERATION. The Design, Construction and Operation of Cupola, J. Wolstenholme. Junior Instn. Engrs., vol. 38, part 1, Oct. 1927, pp. 1-9 and (discussion) 9-12. Covers as far as possible various points requiring consideration; dimensions; construction of shell; blowing apparatus; charging.

DROP FORGING

DIE ROLLINGS, vs. Drop-Forging and Die-Rolling. Iron & Steel World, vol. 1, no. 2, Mar. 1927, pp. 145-146, 3 figs. Discussion of various factors which determine whether particular shape can best be made by drop forging or die rolling.

DROP FORGINGS

FIN FORMATION. Influence of Fin Formation on the Internal Structure of Drop Forgings, E. Decherf. Iron & Steel World, vol. 1, no. 7, Aug. 1927, pp. 489-492, 8 figs.

Factors influencing position and formation of fins in drop forging; value of macrosopic tests in determining flow and internal tension of metal. Translated from Revue Universelle des Mines.

METHODS. Improved Drop Forging Methods, R. W. Peck. Iron & Steel World, vol. 1, no. 4, May 1927, pp. 289-292, 5 figs. Double-impression dies; stamping two or more pieces simultaneously.

ELECTRIC FURNACES

INDUCTION. Industrial Induction Furnaces (Industrieöfen mit Induktionsheizung), E. Russ. Centralblatt der Hütten u. Walzwerke, vol. 31, no. 42, Oct. 19, 1927, pp. 600-602, 5 figs. Description of reheating and muffle furnaces with induction heating, "Russ" and "Industrie" makes.

MELTING. Electric Melting Furnaces Used in Making Steel for Bearings. Fuels & Furnaces, vol. 5, no. 11, Nov. 1927, pp. 1459-1462, 3 figs. Unique design of electric-arc melting furnaces proves very efficient in production of steel for bearings.

ELECTRIC WELDING

RAILWAY TIES. General Electric Metal Railroad Tie Welder. Am. Mach., vol. 67, no. 22, Dec. 1, 1927, p. 875. Welding apparatus consists of automatic tie-welding machine and 1500-ampere motor-generator set with two circuits for hand and two circuits for automatic welding.

ELECTRIC WELDING, ARC

ARC LENGTH. Correct Arc Length, J. B. Green. Welding Engr., vol. 12, no. 10, Oct. 1927, pp. 37-38, 2 figs. Study of metal transfer furnishes basis for determining proper length and practical means for maintaining it. See also Can. Machy., vol. 38, no. 20, Nov. 17, 1927, pp. 21-22.

AUTOMATIC MACHINES. Automatic Arc Welder Makes Railroad Ties from Scrap Rails. Iron Trade Rev., vol. 81, no. 22, Dec. 1, 1927, p. 1358, 3 figs. General Electric Co., Schenectady, N. Y., has developed automatic equipment for performing various welding operations required.

BUILDINGS. A New Arc Welded Building, C. H. Danforth. Am. Welding Soc.—Jl., vol. 6, no. 10, Oct. 1927, pp. 18-24, 4 figs. Method of handling work on new building for Westinghouse High Voltage Insulator Co. at Derry, Pa., permitted entire frame to be erected in place and caught with few bolts, structure being perfectly stable; all connections that had been made by bolts for erection purposes were welded.

BUILDINGS. Arc Welded Building in Berkeley, Calif. Welding Engr., vol. 12, no. 10, Oct. 1927, p. 45, 2 figs. Shop is 50 feet by 250 feet, carrying two 10-ton capacity cranes; structure is entirely welded, no bolts or rivets being employed.

CRANE CONSTRUCTION. Arc Welding Applied to Crane Construction. Elec. World, vol. 90, no. 19, Nov. 5, 1927, pp. 934-935. 10-ton, 60-ft. span electric overhead traveling crane, fabricated entirely by means of arc welding, has been constructed by Cleveland Crane & Eng. Co., Wickliffe, O.

GENERATOR FOR. New Electric Generator for Arc Welding (Nouvelle génératrice auto-régulatrice et auto-excitatrice pour soudure à l'arc), A. Menetrier. Electricité & Mécanique, no. 19, July-Aug., 1927, pp. 20-24, 5 figs. Features of special self-regulating and self-exciting generator solving difficulties due to use of ordinary type of dynamo.

JIGS AND FIXTURES. 30-Minute Jigs and Fixtures Made from Scrap Steel Sections, H. Gonzer. Iron Trade Rev., vol. 81, no. 20, Nov. 17, 1927, pp. 1232-1233, 4 figs. Lincoln Electric Co., Cleveland, employs arc-welding machine which it manufacturers to build its jigs and fixtures for various purposes.

RAILWAY STRUCTURES. Arc Welding For Railway Structures, G. D. Fish. Ry. Club of Pittsburgh—Official Proc., vol. 26, no. 8, Sept. 22, 1927, pp. 186-206 and (discussion) 206-208, 16 figs. Author claims that steady replacement of rivet by electric arc is a great economic movement which cannot be checked by skepticism as to dependability of process; results can be definitely controlled, and failures are as definitely preventable as they are in other engineering operations.

STELLITE. Arc Welding of Stellite, C. M Rusk. Power House, vol. 21, no. 22, Nov. 20, 1927, pp. 43 and 49, 3 figs. Author demonstrates how great savings can be effected in cement mills where grinding rings are reclaimed at low cost and long and costly shutdowns averted by using welded stellite rings.

TANK SEAMS. Arc Welding Tank Seams at High Speeds, R. E. Kinkead. Boiler Maker, vol. 22, no. 11, Nov. 1927, pp. 307-308. Physical tests by E. V. Kesinger of Empire Companies of Bartlesville, Okla.; both average and maximum strength of welds was increased in going from 120-160 amperes to 200 amperes.

FIREBRICK

SLAG CONSTITUENTS. The Slagging of Refractory Materials (Untersuchungen über die Verschlackung feuerfester Stoffe), H. Salmang. Stahl u. Eisen, vol. 47, no. 43, Oct. 27, 1927, pp. 1816-1820, 12 figs. Discusses effect of slag contituents on commerical firebrick.

FORGING

COLD. Cold Forging of Steel, H. W. Miller. Iron & Steel World, vol. 1, no. 3, Apr. 1927, pp. 189-193. With special reference to production of barrels for small guns and liners for larger guns; inner layer of steel is placed in compression by expanding it beyond elastic limit by use of intense hydraulic pressure; discusses economy of process and other possible applications.

DIE DESIGN. Improved Die Design Increases Production, R. Henry. Iron & Steel World, vol. 1, no. 9, Oct. 1927, pp. 637-638. Savings in labor and material result from application of gang forging methods to manufacture of forging of varying cross-section.

DIE DESIGN FOR DEEP PIERCING. Forging Machine Die Design for Deep Piercing, E. R. Frost. Am. Soc. Steel Treating—Trans., vol. 12, no. 6, Dec. 1927, pp. 954-967, 43 figs. Method and die design for producing upset machine forgings having deep holes pierced through them, procedure to be followed in design of dies and piercers, as well as pitfalls to be avoided; kind of material that can be forged; working tempera-

tures, and kind of steel and treatment for piercer tools.

FORGING

SAFETY CODE. Safety Code for Forging and Hot Metal Stamping. U. S. Bur. Labor Statistics—Bul., no. 451, Aug. 1927, 32 pp., 31 figs. Code applies to all classes of power-forging machinery for both drop forging and flat-die forging, including steam hammers, pneumatic hammers, mechanically operated hammers, hydraulic presses, trimming presses, bulldozers, upsetting machine, and bolt-heading and rivet-making machines, hot saws; and incidental operations in connection with such machinery.

FOUNDRIES

AUTOMOBILE - ENGINE CASTINGS. Foundry Effects Substantial Savings, C. H. Vivian. Automotive Mfr., vol. 69, no. 7, Oct. 1927, pp. 5-9. At shop of Campbell, Wyant & Cannon Foundry Co., Muskegon, Mich., most modern methods are utilized to produce 400 tons of motor castings daily; details of procedure in casting room.

FUTURE PROSPECTS. Visualizing Future of the Foundry, H. Pemberton. Foundry Trade Jl., vol. 37, no. 586, Nov. 10, 1927, p. 106. Author states it is not impossible that future will see cast iron melted by means of electric power, instead of cupola, and additionally do this much quicker, with lower losses, under better control, and perhaps cheaper, while undoubtedly ensuring better quality; progress made in developing die castings of various metals; commercial side of foundry work; international trading; advertising and technical press.

MECHANICAL ORGANIZATION. The Mechanical Organization of Foundry Work, M. H. Magdelenat. Foundry Trade Jl., vol. 37, no. 585, Nov. 3, 1927, p. 88. Points out that French markets are not adapted for mass production; in industry in France men are more to be desired than machines, but as this desire is not likely to be fulfilled soon they must resolutely take up mechanical organization of foundry work, preceded by standardization.

PROBLEMS. Paris Foundry Conference Papers. Foundry Trade Jl., vol. 37, no. 583, Oct. 20, 1927, pp. 42-43. Review of following papers: Influence of Cast Iron and Scrap Steel Additions on Quality of the Metal in Blast Furnace Practice, J. L. Jones; Study of Macrostructure of Metals and Non-Ferrous Alloys and Its Applications in Foundry Work, A. Portevin; Curious Example of Thermal Treatment in Cast Iron, Le Thomas and Domanski; Heredity of Cast Iron, A. Levi; Properties of Special Nickel-Manganese Brasses, Le Thomas; Electric Melting of Copper Alloys, R. Lemoine; Use of the Electric Furnace in Iron Foundries, R. Lemoine; Testing and Properties of Foundry Sand, Sirovitch.

RESEARCH. To Promote Work for the Foundry. Iron Age, vol. 120, no. 21, Nov. 24, 1927, pp. 1442-1444. National Founders' Assn. to appoint committee for research into additional manufacturing possibilities; cost accounting also to be furthered.

FURNACES, ANNEALING

CHARGING. New Type of Charger for Sheet-Metal Annealing Furnaces (Neuartige Beschickungsvorrichtung für Blechglühöfen), C. Hoffman. Stahl u. Eisen, vol. 47, no. 44, Nov. 3, 1927, pp. 1874-1876, 3 figs. New charging device, made by F. Krupp, Cruson Works, Magdeburg-Buckau, serves for charging stack of sheets weighing up to 3½ tons, sheets having width of 0.8 to 1.5 m. and length of 3½ m.

SEMI-CONTINUOUS. Annealing Sheet-Metal Shells in a Semi-Continuous Furnace, F. W. Curtis. Am. Mach., vol. 67, no. 21, Nov. 24, 1927, pp. 801-802, 4 figs. Constructional features of annealing furnace that handles annealing of deep-drawn sheet-metal shells economically and with minimum amount of hand labor.

GAGES

METALS FOR. Recent Experiments Relating to the Wear of Plug Gages, H. J. French and H. K. Herschman. Am. Soc. Steel Treating—Trans., vol. 12, no. 6, Dec. 1927, pp. 921-945 and (discussion) 945-953. Results of tests made in laboratory wear tester in gaging file-hard high-carbon steel, an aluminum "piston alloy" and cast iron; in tests made in file-hard high-carbon steel in presence of non-metallic abrasive, stellite, high-carbon high-chromium iron alloy and chromium-plated gages showed better resistance to wear than customary high-carbon steels or Nitralloy.

GAS CLEANING

ELECTRIC. The Elga System of Electric Gas Cleaning in Witkowitz (Die elektrische Grossgasreinigung, Bauart Elga, in Witkowitz. Stahl u. Eisen, vol. 47, no. 46, Nov. 17, 1927, pp. 1933-1939 and (discussion) 1939-1941, 9 figs. Details of installation with capacity of 60,000 cu. m per hr.; plan for increasing capacity to 240,000 cu. m. per hr.; comparison between wet and electric cleaning from economic viewpoint.

HARDNESS

TESTING, DYNAMIC. The Ball Impact Hardness Tester (Der Kugelschlaghärteprüfer), J. Class. Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, no. 296, 1927, 20 pp., 18 figs. Laws of ball pressure test; ball impact test in comparison with ball pressure and ball drop test, results of experiments, their degree of precision, calibration chart of impact hardness test for steel and iron.

IMPACT TESTING

BOILER PLATE. Impact Tests of Notched Specimens of Boiler Plate (Zur Durchführung der Kerbschlagprobe mit Kesselblechen), R. Baumann. Zeit. des Bayerischen Revisions-Vereins, vol. 31, nos. 16 and 17, Aug. 31 and Sept. 15, 1927, pp. 173-177 and 186-190, 22 figs. Study of experiments on effect of temperature on impact strength of various types of treated boiler plate; commends ordinary testing procedure, and sees no special advantage in more laborious tests recommended by German Society for Testing Materials.

IRON

CHEMICAL CORROSION. Effect of Brines and Salts on Iron (Untersuchungen über die Einwirkung von Laugen und verschiedenen Salzen auf Eisen), K. Taussig. Archiv für

Wärmewirtschaft, vol. 8, no. 11, Nov. 1927, pp. 337-340. Critical discussion of study by Berl, Standinger and Plagge; high salt concentrations are always dangerous, the more so at high pressures; pure distillates are, however, not harmful.

INTERACTION WITH OTHER SOLIDS. Behavior of Iron in Presence of Other Elements (Das Verhalten des Eisens zu anderen Elementen), G. Tammann and K. Schaarwächter. Zeit. für anorganische u. allgemeine Chemie, vol. 167, no. 3-4, Nov. 1, 1927, pp. 401-410, 12 figs. Determinations of heating curves of iron with sulphur, phosphorus, calcium, aluminum, tin, graphite, silica etc.

IRON ALLOYS

IRON-OXYGEN. The Iron-Oxygen System (Ueber das System Eisen-Sauerstoff), C. Benedicks and H. Löfquist. V. D. I. Zeit., vol. 71, no. 45, Nov. 5, 1927, pp. 1576-1577, 1 fig. Summary of phase rule studies of system, presents diagram of state according to C. Benedicks and H. Löfquist. Bibliography.

IRON AND STEEL

CENSUS OF MANUFACTURERS. Iron and Steel. U. S. Bur. of Census—Report, 1927, 63 pp. Blast furnaces, steel works and rolling mills; tin-plate and terneplate; wire; wirework, not elsewhere classified; cast-iron pipe.

ELECTRICAL MACHINERY. Use of Steel and Iron in Construction of Electrical Machinery (Stahl und Eisen im Elektromaschinenbau), F. Laszlo. V. D. I. Zeit., vol. 71, no. 44, Oct. 29, 1927, pp. 1539-1547. Special requirements of electrical machinery and ways of meeting them, steels and irons generally used, special alloys for electrical apparatus.

GERMAN MATERIALS SHOW. The Materials Show of Berlin, 1927 (Die Werkstoffschau Berlin 1927). Stahl u. Eisen, vol. 47, no. 42, Oct. 20, 1927, pp. 1743-1778, 35 figs. General description of exposition, details of iron and steel divisions, noting most interesting exhibits of steels, alloys and steel tools and machine parts.

RESEARCH. The Kaiser-Wilhelm Institut for Iron and Steel Research at Düsseldorf (Das Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf), F. Körber. Stahl u. Eisen, vol. 47, no. 42, Oct. 20, 1927, pp. 1737-1743, 7 figs. History of institute and description of equipment and shops of departments of ore dressing, mechanics, metallurgy, physics, chemistry, etc.

IRON CASTINGS

GRAY. Rules for the Construction of Iron Castings (Konstruktionsregeln für Grauguss), R. Lehmann. Giesserei, vol. 14, nos. 41, 42, 44 and 45, Oct. 8, 15, 29 and Nov. 5, 1927, pp. 682-685, 701-705, 765-770 and 784-790, 3 figs. Discusses rules for design of gray-iron castings formulated by German Committee on Economic Production.

MINE TUBBINGS. The Manufacture of Cast-Iron. Tubbings for Mine Shafts, H. Becker. Foundry Trade Jl., vol. 37, no. 586, Nov. 10, 1927, pp. 107-108, 4 figs. Deals with cast-iron tubbings, which are those most generally in use; German tubbings are provided with machined flanges; machining of separate segments, and of the completed rings.

LEAD ALLOYS

PRINTING TYPE. Printing Type Alloys of Lead and Tin (Contribution à l' étude des alliages d' imprimerie et des métaux plomb et étain), A. Trayers and Houot. Revue de Metallurgie, vol. 24, no. 9, Sept. 1927, pp. 541-554, 16 figs. Experimental study of heat expansion and tempering of ternary and binary alloys of lead, tin and antimony, also of allotropic forms of tin and properties of commercially pure tin.

LUBRICATION

STEEL-MILL EQUIPMENT. Lubrication of Steel Mill Equipment, A. F. Brewer. Iron & Steel World, vol. 1, nos. 1, 2, 3, 4, 5, 6 and 7, Feb., Mar., Apr., May, June, July and Aug., 1927, pp. 17-20, 117-122 and 133, 183-187, 255-259, 353-356, 399-402 and 479-482, 35 figs. Feb.; Selection of lubricants for various applications and conditions; importance of properties of lubricants and method of testing for viscosity, pour test, flash point, fire point, carbon content. Mar.: Storage and handling of lubricants. Apr.: Reconditioning. May: Principles of automatic lubrication. June: Wire-rope lubrication. July: Gear lubrication. Aug.: Electric motor bearings.

MAGNESIUM ALLOYS

DISSOLUTION, RATE OF. Rate of Dissolution of Ultra-Light Magnesium Alloys (Etude de la vitesse de dissolution des alliages du magnésium ultra-legers), A. Portevin and E. Pretet. Académie des Sciences—Comptes Rendus, vol. 185, no. 2, July 11, 1927, pp. 125-127. Rates of corrosion of pure magnesium by O. IN-hydrochloric and citric acids have been compared with those of its ultra-light alloys by various methods; pure magnesium is less attackable than its alloys but this property is modified by presence of silicon.

MANGANESE STEEL

LOW-CARBON. Some Characteristics of Low-carbon Manganese Steel, V. N. Krivobok, B. M. Larsen, W. B. Skinkle and W. C. Masters. Am. Inst. Min. & Met. Engrs.—Tech. Publication, no. 24, Nov. 1927, 30 pp., 32 figs. It can be manufactured in either basic or acid open-hearth or electric furnaces, available manganese alloys giving any desired composition; finishing of manganese heat in furnace, and use of silicomanganese for making low-carbon heats involve special problems in furnace operation which are not yet entirely solved and deserve further study; it may be useful chiefly in field of cheaper alloy steels, where large tonnages are desired of steel with properties superior to those of ordinary open-hearth carbon steels; double heat treatment is necessary to bring out best properties.

METALLOGRAPHY

POLISHING OF SAMPLES. Preparation of Aluminum Oxide for Final Polishing and the Preservation of Polished and Etched Surfaces, W. P. Fishel. Am. Soc. Steel Treating—Trans., vol. 12, no. 6, Dec. 1927, pp. 982-983. Two processes described were developed in Metallographic Laboratory of

Vanderbilt Univ., Nashville, Tenn.: preservation of polished metal surfaces.

METAL SPRAYING

MOLTEN METALS. Coating by Molten-metal Spraying, R. L. Binder. Machy. (N. Y.), vol. 34, no. 3, Nov. 1927, pp. 169-175, 14 figs. Process of coating metals or other materials by spraying molten metal against surface to be coated; review covering latest forms of apparatus and some of typical, as well as more unusual, operations.

METAL WORKING

DEEP DRAWING. The Deep Drawing of Steel and Other Metals. Iron & Steel World, vol. 1, no. 5, June 1927, pp. 357-360, 5 figs. Reviews three German bulletins for purpose of acquainting American engineers and manufacturers with scientific progress made elsewhere.

METALS

AIRCRAFT. Materials for Aircraft Parts Subjected to High Temperatures, J. B. Johnson. Am. Soc. Mech. Engrs.—advance paper for mtg. Dec. 5-8, 1927, 6 pp., 11 figs. Operating conditions and materials now being used; desirability of developing better materials to meet requirements of modern design.

AIRCRAFT. Selection of Materials for Aircraft Structures, J. A. Roche. Soc. Automotive Engrs.—Jl., vol. 21, no. 5, Nov. 1927, pp. 494-496. Formulas giving rational criteria for design of airplane members and for selection of most suitable materials taking due account of physical properties of aircraft materials and of resistance that results from proper use of each: tables of relative strength values show which materials are best for various parts and how much weight it is wise to add for given reduction in parasite resistance or for given increase in output of power plant; properties of various materials are studied separately with relation to their functions, and indices are given classifying them in order of their merit for tension and compression, and for beams and columns.

COLD-ROLLED. The Structure of Cold-Rolled Metals (Beiträge zur Kenntnis der Struktur kaltgewalzter Metalle), F. Wever and W. Schmidt. Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf, vol. 9, no. 17, paper no. 90, 1927, pp. 265-272, 39 figs. partly on supp. plates. Deals with structure analysis of rolled aluminum, copper and silver; recrystallization process of aluminum.

IMPURITIES Impurities. Metallurgist (Supp. to Engineer), Nov. 25, 1927, pp. 162-163. In cases mentioned effects of impurities are most important from point of view of mechanical properties of metals and alloys concerned; from viewpoint of electrical industry, however, electrical and magnetic properties are even more important, and this opens up wider field of research and one involving study of much more minute quantities of impurity as affecting properties of high-purity metals.

INTERNAL STRESSES. Internal Stresses in Metals (Innere Spannungen in Metallen), G. Sachs. V. D. I. Zeit., vol. 71, no. 43, Oct. 22, 1927, pp. 1511-1516, 29 figs. Results of study at Kaiser-Wilhelm-Institut on cracking and failure of cold-rolled cylinders made of brass, duralumin or other metals when exposed to action of liquid chemicals or heat. corrective effect of hammering and annealing; discussion of "Bauschinger effect", i. e., lowering of elastic limit on account of minute strains; methods of measuring internal stresses.

OLD, CLASSIFICATION. New Tentative Standard Classification for Old Metals. Metal Industry (N. Y.), vol. 25, no. 11, Nov. 1927, pp. 463-464. Drawn up by Committee and approved at meeting of Metal Division of National Association of Waste Material Dealers.

PICKLING. Brittleness Due to Pickling, H. Bablik. Iron & Steel World, vol. 1, no. 9, Oct. 1927, pp. 635-636. Causes of brittleness and blistering and means of overcoming them; effect of temperature and concentration of solution on pickling action.

RECRYSTALLIZATION. Recrystallization of Silver and Copper (Untersuchungen über die Rekristallisation bei Silber und Kupfer), H. Widmann. Zeit. für Physik, vol. 45, no. ¾, 1927, pp. 200-224, 18 figs. X-ray study of effects of heavy rolling and heat treatment on crystalline structure, texture and mechanical properties; effect of slight impurity on lower limit of temperature of recrystallization.

TESTING. Mechanical Testing of Materials, R. W. Bailey. Engineering, vol. 124, nos. 3226 and 3228, Nov. 11 and 18, 1927, pp. 622-625 and 663-666, 37 figs. Confines attention chiefly to works testing of metals employed in construction of important high-speed machinery; purpose of tests is to ascertain or ensure mechanical soundness of materials. Paper read before Instn. Mech. Engrs.

YIELD POINT. The Yield Point in Testing of Materials (Die Streckgrenze in der Werkstoffprüfung), F. Körber. Centralblatt der Hütten u. Walzewerke, vol. 31, no. 41, Oct. 12, 1927, pp. 581-584, 6 figs. General discussion noting lack of agreement on definition of phenomenon and on standard methods for determining it.

MOLYBDENUM

USES. Molybdenum and Its Uses, W. H. Phillips. Can. Machy., vol. 38, no. 18, Nov. 3, 1927, pp. 23-24. Forging and rolling; ease with which molybdenum can be added to iron or steel insures good results in melting operation; alloy recovery is exceptionally high, running up to 98 to 99 per cent; molybdenum in all scrap can be fully recovered; its use in iron. Abstract of lecture presented before Montreal Chapter of Am. Soc. for Steel Treating.

NICKEL

HISTORY AND USES. Nickel—Past and Present, R. C. Stanley. Metal Industry (Lond.), vol. 31, nos. 10, 13, and 14, Sept. 9, 30 and Oct. 7, 1927, pp. 227-229, 298-300 and 325-327. Development and uses of nickel; Canadian resources; nickel-steel. Sept. 30: Industrial uses of nickel; nickel-silver; nickel-plating; copper-nickel alloys; Monel metal. Oct. 7: Heat-resisting and electrical alloys; malleable nickel; nickel bronzes; corrosion-resistant steels; ferronickel alloys; nickel cast iron; miscellaneous alloys.

NICKEL ALLOYS

PERMALLOY. Permalloy: The Latest Step in the Evolution of the Loading Coil. Bell Telephone Quarterly, vol. 6, no. 4, Oct. 1927, pp. 238-246, 5 figs. Properties and uses of alloy of 80 per cent of nickel and 20 per cent of iron, specially heat treated; one of its first important applications was to continuous loading of transoceanic telegraph cables, where high magnetic permeability which this substances affords was prime requisite; its use in loading-coil construction.

NON-FERROUS METALS

CASTINGS. Influence of Chemical and Crystallographic Properties of Casting Metal on Behavior During Rolling, E. Seidl. Min. & Met., vol. 8, no. 251, Nov. 1927, pp. 454-460, 24 figs. Fundamental phenomena during solidification of cast metals are identical in case of aluminum, copper, and zinc investigated; for casting texture in its relation to conditions of cooling is determined by certain laws of nature; experience has actually proved that it is possible to obtain casting texture as mentioned providing following method is adopted: Strict maintenance of just that casting temperature which experience has shown to be most favorable for metal in question; use of thick-walled molds capable of quickly transmitting heat; great quickness in casting operations.

ELECTRIC USES. Use of Non-Ferrous Metals in Electrical Engineering (Die Nichteisenmetalle in der Elektrotechnik), W. Wunder. V. D. I Zeit., vol. 71, no. 44, Oct. 29, 1927, pp. 1548-1552, 7 figs. Electrical uses of following metals and their alloys: copper, aluminum, magnesium, zinc, lead, tin, nickel, silver, tungsten, bismuth, etc.

ENGINEERING. Non-Ferrous Metals in Engineering, H. Fowler. Metal Industry (Lond.), vol. 31, no. 18, Nov. 4, 1927, pp. 413-415. Deals with light alloys; high-temperature-resisting metals; magnesium; cadmium and chromium for plating; problem of cohesion; lubrication problems. Abstract of paper read before Instn. Mech. Engrs.

TECHNICAL. Engineering Non-Ferrous Alloys, A. K Gold. S. African Instn. Engrs.—Jl., vol. 26, no. 3, Oct. 1927, pp. 50-60, 10 figs. Attention is confined to those alloys in general use; indicated importance of structure in non-ferrous alloys, and its relation to their mechanical properties; deals with gun metals, tin and phosphor bronzes, brasses, aluminum bronze, aluminum alloys and white metals.

OPEN-HEARTH FURNACES

HEAT BALANCE. The Heat Balance of Open-Hearth Furnaces with special Regard to Exhaust-Gas Losses (Die Wärmebilanz des Siemens-Martin-Ofens unter besonderer Berücksichtigung der Abgasverluste, C. Schwarz. Archiv für das Eisenhüttenwesen, vol. 1, no. 4, Oct. 1927, pp. 273-281, and (discussion) 281-283, 7 figs. Calculation of effective heat based on existing literature; hearth-chamber losses; relation between preheating, flame temperature with and without dissociation, and heat volumes available with cooling. See abstract in Stahl u. Eisen, vol. 47, no. 46, Nov. 17, 1927, pp. 1954-1955.

PROBLEMS. Discuss Open-Hearth Problems. Iron Age, vol. 120, nos. 19 and 20, Nov. 10 and 17, 1927, pp. 1320-1322 and 1376-1379 and 1424. Review of papers presented at conference of open-hearth operators, under auspices of Am. Inst. of Min. & Met. Engrs.

REFRACTORIES. Open-Hearth Steelworks Refractories, A. T. Green. Foundry Trade Jl., vol. 37, no. 583, Oct. 20, 1927, pp. 50-52. Bricks for port and top courses; highly converted silica unsuitable for open-hearth; corrosion and erosion of open-hearth silica bricks; mechanism of corrosion and erosion; bricks from furnace roofs; thermal characteristics of chequerwork; materials for regenerators.

OXYACETYLENE CUTTING

CAST IRON. Oxyacetylene Cutting of Cast Iron (Le découpage de la fonte au chalumeau oxy-acétylenique), M. Piette. Revue de la Soundure Autogène, vol. 19, no. 163, Sept. 1927, pp. 1415-1418, 9 figs. Description of cutting blowpipe with photographs and particulars of various cuts made commerically.

OXYACETYLENE WELDING

AIRCRAFT CONSTRUCTION. The Welded Joint in Aircraft Construction, W. C. Naylor. Am. Welding Soc.—Jl., vol. 6, no. 10, Oct. 1927, pp. 8-17, 8 figs. In case of some assemblies such as fuselage, empennage, motor mount and tail skid practically entire industry with exception of those companies specializing in duralumin construction has standardized on welded steel-tube construction; low cost, combined with strength, lightness and rapidity of manufacture, account for general use of this method.

CORROSION-RESISTING ALLOYS. Welding Corrosion Resisting Alloys. Acetylene Jl., vol. 29, no. 5, Nov. 1927, pp. 185-187, 3 figs. Deals with oxyacetylene welding of Duriron and Alcumite; welded joint offers means of fabricating durable acid-resisting installations.

ANNEALING PIPE JOINTS. Annealing Welded Pipe Joints. Acetylene Jl., vol. 29, no. 5, Nov. 1927, pp. 195-196, 3 figs. High-pressure steam main, 18 in. in diameter with steel wall ½ in. thick was constructed with chamfered edges, for oxyacetylene welding of joints, following completion of each weld, all joints were annealed six inches on each side of weld, being heat treated with use of McKneat atomizing burner.

INFORMATION AND INSTRUCTION. Gas Welding and Cutting. Am. Welding Soc.—Jl., vol. 6, no. 10, Oct. 1927, pp. 5-83, 51 figs. Instructions for beginners in gas welding and cutting compiled by Educational Committee of Am. Welding Soc.

PIPE LINES. 500,000 Ft. of Welded Piping in One Building, C. Kandel. Acetylene Jl., vol. 29, no. 5, Nov. 1927, p. 202. In erection of new 16-story Nurses' Home, forming part of Mt. Sinai Hospital, New York, all steam, brine and hot-water pipe lines were welded.

PRACTICAL APPLICATIONS. Practical Oxy-Acetylene Welding, R. Granjon, P. Rosemberg and A. Desgranges. Welding Jl., vol. 24, nos. 284, 285, 286, 287, 288, and 289, May, June, July, Aug., Sept., and Oct. 1927. pp. 140-143, 174-176, 208-211, 237-239, 264-266, and 319-321, 142 figs. May: Welding of cast iron. June: Special and

malleable cast iron; welding of aluminum. July: Light alloy of aluminum. Aug.: Duralumin and special alloys, welding of copper. Sept.: Welding of brasses. Oct.: Bronzes and Miscellaneous metals and alloys

PRESSURE VESSELS. Searching Tests of Welded Joints. Iron Age, vol. 120, no. 21, Nov. 24, 1927, pp. 1445-1446. Sponsored by International Acetylene Assn. in study of pressure vessels; value of various gases for cutting flame compared.

PRESSURE VESSELS. Study of Oxy-Acetylene Welding as Applied to Light Gauge Pressure Containers, H. J. Grow. Am. Welding Soc.—Jl., vol. 6, no. 10, Oct. 1927, pp. 25-43, 11 figs. Explanation of rudiments of welding practice applicable to products of such nature; covers principal mechanical problems of sizing and forming of material.

STEEL BARRELS. Gas Welding Makes Better Barrels. Acetylene Jl., vol. 29, no. 5, Nov. 1927, pp. 188-190. Practice and equipment of Niedringhaus, Inc., of St. Louis, manufacturers of steel barrels and drums, used mostly as means of shipping gasoline and naphtha.

THEORY AND PRACTICE. Theory and Practice of Autogenous Welding (Theorie und Praxis der autogenen Schweissung), C. F. Keel. Eidgenössische Materialprüfungsanstalt an der E. T. H. in Zurich, no. 11, May 1926, 52 pp., including discussion, 90 figs. Deals with raw materials, apparatus and tools; quality of welds; arrangement of seams; results of tests on welds; welding of cast iron; describes new welding method.

PIPE, CAST-IRON

BRONZE-WELDING. New High Strength Joint. Oxyacetylene Tips, vol. 6, no. 4, Nov. 1927, pp. 72-76, 5 figs. Shear-vee type joint for bronze-welding cast-iron pipe develops practically full strength of pipe.

CENTRIFUGALLY CAST. Cast Iron Pipe Centrifugally Made Sand Molds, J. T. MacKenzie. Am. Iron & Steel Inst.—advance paper, for mtg., Oct. 28, 1927, 13 pp., 4 figs. Presents tabulation of results obtained by Professor Talbot on pit-cast and centrifugally sand-cast pipe. See also Iron Age, vol. 120, no. 19, Nov. 10, 1927, p. 1302.

PHOTOELASTICITY

STRESS ANALYSIS. Photo-Elastic Investigations of the Tensile Test Specimen, the Notched Bar, the Ship Propeller Strut, and the Roller Path Ring, H. B. Maris. Optical Soc. of Am.—Jl., vol. 15, no. 4, Oct. 1927, pp. 203-237, 25 figs. Describes methods of photoelastic analysis, including new ways of measuring both double refraction and deformation resulting from stress; in each case new facts concerning strain members have been brought out very simply by experimental photoelastic method, facts which would be difficult of discovery by direct mathematical analysis.

PYROMETERS

Optical. Optical Pyrometer and Distance Thermometers. Engineering, vol. 124, no. 3224, Oct. 28, 1927, p. 550, 2 figs. Instruments made by Siemens Bros. & Co., Woolwich, England; portable pyrometer is of disappearing filament type.

REFRACTORIES

CHEMICAL INVESTIGATION. The Chemical Investigation of Refractories (Die chemischen Untersuchung von feuerfesten Stoffen), H. J. van Royen. Stahl u. Eisen, vol. 47, no. 41, Oct. 13, 1927, pp. 1696-1697. Investigation of quartzites and silica brick; rapid method for investigation of silica raw materials; investigation of firebrick and clay.

ROLLING MILLS

BELT vs. ELECTRIC DRIVE. New Drives for Plate Rolling Mills (Neuartige Antriebe von Blechwalzwerken). Kruppsche Monatshefte, vol. 8, June-July 1927, pp. 121-125, 10 figs. Describes some recent mills with belt transmission instead of direct coupled electric motor drive, as result of which great diameter and weight of flywheels is reduced to about one half or less.

BLOOMING MILLS. An Automatic Blooming Mill for a Strip Steel Rolling Mill (Eine automatische Vorstrasse für ein Bandeisenwalzwerk), A. Schöpf. Centralblatt der Hütten u. Walzewerke, vol. 31, no. 41, Oct. 12, 1927, pp. 584-586, 5 figs. Describes mill which delivers high-quality hot bars of varying cross-section to finishing mill.

CALCULATIONS. Rolling Mill Calculations, J. D. Keller. Iron & Steel World, vol. 1, nos. 1, 2, 3, 4 and 5, Feb., Mar., Apr., May and June, 1927, pp. 37-42, 127-130, 199-200, 271-276 and 343-346, 20 figs. Analysis of stresses in 44-in. blooming mill for determining constants for use in design of new mills. Feb.: Gripping or biting of steel by rolls; stresses in rolls. Mar.: Maximum bearing pressure on roll necks; stresses in housings, screws and screw-box. Apr.: Torsional strength of spindles and wobbler; stresses in pinions. May: Means to prevent overheating of motors. June: Time in mill approximately equals time on tables.

ELECTRIC DRIVE. Cold Rolling Mill of Recent Design, E. W. Duston. Blast Furnace & Steel Plant, vol. 15, no. 11, Nov. 1927, p. 551, 1 fig. Special design of electrically driven mill of six units which offers several distinct advantages, especially in manufacture of bolts and nuts.

ELECTRIC DRIVE. Main Drives 10″ Merchant Mill at McKinney Steel Company, A. F. Kenyon. Iron & Steel Engr., vol. 4, no. 11, Nov. 1927, pp. 455-457, 7 figs. Mill has roughing train driven by 1000-hp., 200/600-r.p.m. motor, an intermediate train driven by 2000-hp., 137/275-r.p.m. motor and four finishing stands driven by 1200-hp. 300/550-r.p.m. motor.

FOUR-HIGH. Developments in Four-High Rolling, F. C. Biggert, Jr. Iron Age, vol. 120, no. 20, Nov. 17, 1927, pp. 1367-1370. Mill and roll design matured rapidly; roller bearings large factor; high tonnage output. Paper read before Iron & Steel Division of Am. Soc. Mech. Engrs.

MANNESMANN PROCESS. Fundamentals of Mannesmann Process (Grundsätzliche Betrachtungen zum Schrägwalzverfahren), E. Siebel. Stahl u. Eisen, vol. 47, no. 41, Oct. 13, 1927, pp. 1685-1691, 16 figs. Mechanical theory and metallographic studies of stresses and deformations induced by diagonal rolling give only qualitative picture; further research on friction between rolls and rolled specimen and on similar problems of me-

chanics of rolling necessary to form quantitative picture of process.

MEASURING GAGE OF ROLLED STOCK. Continuous Measurement of Gauge of Rolled and Drawn Materials, H. Wilde. Iron & Steel World, vol. 1, no. 3, Apr. 1927, pp. 214-216, 2 figs. Apparatus consists of stationary roller beneath stock and movable roller above stock which transmits variation in distance between rollers, through lever to mirror which reflects beam of light on magnified scale. Translated from Zeit. für Feinmechanik u. Präzision.

REFRACTORIES FOR. Refractories and Four-High Mills. Iron Age, vol. 120, no. 20, Nov. 17, 1927, pp. 1370-1371. Review of papers read before iron and steel division of Am. Soc. Mech. Engrs.

ROD MILLS. High-Speed Continuous Rod Mill, J. Nelson. Iron Age, vol. 120, no. 19, Nov. 10, 1927, pp. 1297-1299. New Morgan billet mill and rod mill were put in operation at South works of Am. Steel & Wire Co., Worcester, Mass.; rod mill is said to roll wire rods at faster rate than they were produced before either in America or abroad; capacity output in 24 hr. is 2200 miles of wire rods; annual output is 100,000 tons; billet mill is unusual in two respects; slight adaptation of spacing of roll stands makes it possible to roll standard copper ingots as well as steel blooms; other feature is provision for rolling, shearing and cooling of slabs, up to 2 in. thick and 7 in. wide.

ROD MILLS. New Continuous Rod Mill Employs Muffle Conveyor. Iron Trade Rev., vol. 81, no. 19. Nov. 10, 1927, pp. 1166-1168, 4 figs. Am. Steel & Wire Co., on site of old Washburn wire factory, has put into operation one of world's speediest continuous rod mills; these mills take 2x2-inch billets at one end of a continuous train of rolls, and at other end deliver a No. 7 rod, 0.177-inch diameter, at rate of 4200 ft per min.; in sequence from billets to rods, 20 reductions are required.

ROD-SWITCHING DEVICE. Rolling Mill Rod-Switching Device, A. G. Ripberger. Machy. (N. Y.), vol. 34, no. 4, Dec. 1927, pp. 262-263, 2 figs. Plan of guides and device for switching variable rod lengths alternately on two reels; mechanism of automatic switching device.

SHEET AND TIN. Use of Steam on Sheet and Tin Mills for Reducing Roll Temperatures, W. H. Melaney. Iron & Steel World, vol. 1, no. 1, Feb. 1927, pp. 27-30. One of problems that must be met especially where tonnage as well as quality of sheets is factor is prevention of too great "puffing up"; due to over-expansion of center of rolls.

SPREAD IN ROLLING. Investigation of the Flow of Material in Rolling (Experimentelle Untersuchungen über den Materialfluss beim Walzen), N. Metz. Stahl u. Eisen, vol. 47, no. 44, Nov. 3, 1927, pp. 1872-1874. Reviews results of experimental investigations.

STEAM ECONOMICS IN. Steam Economics in a Steel and Rolling Mill (Dampfwirtschaft in einem Stahl- und Walzwerk), H. Wilhelm. Stahl u. Eisen, vol. 47, no. 45, Nov. 10, 1927, pp. 1903-1907, 10 figs. Discusses means of reducing power costs, based on example of boiler plant of steel and rolling mill; gives steam requirement and production conditions and describes waste-heat boiler, feed-water storage, etc.

STRIP MILLS. The Stripsteel Mill of the Columbia Steel Company, A. H. Blaisdell. Iron & Steel World, vol. 1, no. 6, July 1927, pp. 415-422, 9 figs. Entire process of manufacturing sheet material proceeds with notable absence of human element but with smoothness and regularity of well designed and constructed machine.

THREE-HIGH. Design of Three High Roughing Rolls for Maximum Service, H. Cramer. Iron & Steel World, vol. 1, no. 7, Aug. 1927, pp. 497-502, 9 figs. Relation of diameter reduction to side wear and pass taper; simple and combined method of turning rolls; wearing possibilities of rolls of three-high roughing mill as illustration. Translated from Stahl u. Eisen.

WATER APPLIED TO ROLLS. Use of Water on Rolls to Improve Operation of Mills, W. Trinks. Iron & Steel World, vol. 1, no. 3, Apr. 1927, pp. 131-133. Effect of water on operation of mills.

ROLLS

ROUGHING. Recommendations to Avoid the Roughing of Rolls, H. Sedlaczek. Iron & Steel World, vol. 1, no. 3, Apr. 1927, pp. 201-203, 2 figs. In development of roll-pass design, question of gripping is governing factor for determination of draft, also for number of passes and output; from data presented it can readily be seen that in many cases described roughing of rolls is avoided without reducing draft and clean final product is obtained, saving rolls and increasing their life. Translated from Stahl u. Eisen.

TUBE-SIZING AND STRAIGHTENING. Tube Sizing and Straightening Rolls. Iron Age, vol. 120, no. 22, Dec. 1, 1927, p. 1525, 1 fig. Dane & Roach, Syracuse, N. Y., have placed on market a new roll which is available in number of sizes; in this machine horizontal roll shafts are gear driven and vertical roll shafts are idlers.

SHEET STEEL

TESTING. Observations on Testing of Sheet Steel, Blast Furnace & Steel Plant, vol. 15, no. 11, Nov. 1927, pp. 528-531, 14 figs. Comparison of testing methods and internal defects noted in deep and extra deep drawing of sheet steel; segregation, inclusions, etc., considered.

SLAG

BLAST-FURNACE. Composition of Iron Blast Furnace Slags, R. S. McCaffery. Am. Inst. Min. & Met. Engrs.—Tech. Publication, no. 19, Nov. 1927, 42 pp., 14 figs. As blast-furnace slags are included in silica-alumina-lime-magnesia system, which is particular case of four-component solutions, authors have determined that there are 22 components which may enter into silica-alumina-lime-magnesia system and that 10 or 12 of these components may be present in blast-furnace slags which are within ordinary ranges of composition; they have developed theory of cooling of four-component solution from liquid state to solid and conclusions obtained have been made use of. Includes discussion.

BRICK FROM. Slag Brick and Slag Pavement in Germany (Schlackensteine und Schlackenpflastersteine in Deutschland), A.

Guttmann. Archiv für Eisenhüttenwesen, vol. 1, no. 5, Nov. 1927, pp. 339-344, 7 figs. Discusses different production processes for slag brick and adaptability of blast-furnace slags for this purpose; properties of slag brick and suggestion for strength specifications.

SPRINGS

FATIGUE STRENGTH. Steel Springs and Fatigue Strength, A. L. Walker. Mech. World, vol. 82, no. 2130, Oct. 28, 1927, pp. 322-323. Résumé of outstanding facts of repeated stress of steel springs.

STEEL

AMMONIA SYNTHESIS, FOR. Steels Best for Nitrogen Fixation, J. G. Thompson. Iron Age, vol. 120, no. 22, Dec. 1, 1927, pp. 1518-1520, 8 figs. studies have shown conclusively that exposure of steels in conditions described causes decarbonization; fissuring, voiding or porosity in affected zones; lowered strength and ductility; and sharp increase in combined nitrogen in affected zones or higher chromium steels; all evidence to date points to desirability of low-carbon, chromium-rich steel for construction of apparatus for synthesis of ammonia.

CARBON DISTRIBUTION. Segregation of Dissolved Elements and Its Influence Upon Carbon Distribution in Steel, E. G. Mahin and H. J. Dillon. Am. Soc. Steel Treating—Trans., vol. 12, no. 6, Dec. 1927, pp 905-919 and (discussion) 919-920. Accounts of theories that have been advanced to explain common coincidence of non-metallic inclusions and proeutectoid ferrite or cementite in annealed steels, these theories are classified as mechanical, chemical and physical; evidence is cited to support theory that slight solubility of most inclusions in austenite, with resulting contamination of microscopic zones surrounding these inclusions, is responsible for changes in phase relations, excess of proeutectoid phase being precipitated first in these regions; segregation of dissolved impurities causes weakness, first because of irregularity in composition with respect to these impurities, second because of ferrite segregation which is consequence of such irregularity.

CARBON IN. The Determination of Carbon in Iron and Steel according to the Barite process (Ueber die Bestimmung des Kohlenstoffs in Eisen und Stahl nach dem Barytverfahren), G. Thanheiser and P. Dickens. Mitteilungen aus dem Kaiser-Wilhelm Institut für Eisenforschung zu Düsseldorf, vol. 9, no. 15, paper no. 88, pp. 239-245, 5 figs. For accurate determination of carbon in carbon-poor steels according to Barite process, apparatus was developed with which it is possible at the same time to carry out titimetric and weight-analysis determinations.

CARBON, STRUCTURE OF. X-ray Investigation of the Structural Carbon Steel (Eine röntgengraphische Untersuchung der Struktur des Kohlenstoffstahls), N. Seljakow, G. Kurdjumow and N. Goodstow. Zeit. für Physik, vol. 45, no. 5/6, 1927, pp. 384-408, 19 figs. Methods and apparatus used in investigation by Leningrad laboratory for technical physics and the metallographic laboratory of steelworks (Krasniy Putilovetz), which established existence of a centered-tetragonal strucure in hardened carbon steel which differs but little from that of iron; suggests that hardened carbon steel may be regarded as transition phase between the X and Y structures.

COMPRESSION AND BREAKING ENERGY. Influence of Compression Upon the Breaking Energy of Steel (Influence de la compression sur la fragilité de l' acier. Existence d' une limite de fragilité), P. Dejean and H. Le Chatelier. Académie des Sciences—Comptes Rendus, vol. 184, no. 4, Jan. 24, 1927, pp. 188-189. Investigation to determine what influence, if any, preliminary compression exerts upon energy necessary to fracture steel specimens under usual impact test. See brief translated abstract in Mech. World, vol. 82, no. 2128, Oct. 14, 1927, p. 295.

CONTRACTS AND TESTS. Co-operation of Steel Producers with Steel Users (Gemeinschaftsarbeit der Stahl erzeugenden und verbrauchenden Industrie bei Werkstofffragen), P. Goerens. Stahl u. Eisen, vol. 47, no. 42, Oct. 20, 1927, pp. 1726-1732, 6 figs. Discusses principles governing selection and testing of steels, particularly contracts, acceptance tests and proving methods.

COPPER ADDITIONS. The Resistance to Corrosion of Steel Containing Copper (L' acier au cuivre, sa resistance à la corrosion), M. Grison and L. Le Page. Revue de Métallurgie, vol. 24, no. 6, June 1927, pp. 331-336, 1 fig. Tests carried out with object of comparing behavior under identical conditions of samples of ordinary mild steel and of mild steel containing copper; data show that copper steel was superior to carbon steel in all tests employed, and especially in sulphuric-acid solution; authors conclude that price of mild steel containing 0.5 to 0.7 per cent copper should not prevent its application in large structures, where its resistance to corrosion would make it particularly useful. See also translated abstract in Metallurgist (Supp. to Engineer), Nov. 25, 1927, p. 172.

DECARBURIZATION. Surface Decarburization of Carbon Steels (Ueber die Randentkohlung von Kohlenstoffstählen), E. H. Schulz and W. Hülsbruch. Stahl u. Eisen, vol. 47, no. 41, Oct. 13, 1927, pp. 1694-1695. Most striking result, which seems to be fully demonstrated by experimental evidence, is that what is usually regarded as "neutral" gas, becomes strongly decarburizing when contaminated with small percentage of oxygen or of oxygen-bearing gases; heating in salt-bath (mixed chlorides) was also found to produce decarburization; formation of scale on surface of steel tends to diminish and even substantially to prevent decarburization; decarburization occurs below carbon change point and is not, even at such relatively low temperatures, confined to immediate surface; suggest that where scaling can be permitted, heating with free access of air is far less injurious, so far as decarburization is concerned, than heating in so-called reducing atmosphere, unless oxygen can be entirely excluded from latter. Complete article in Archiv für das Eisenhüttenwesen, vol. 1, no. 3, Sept. 1927, pp. 225-240, 45 figs.; and translated abstract in Metallurgist (Supp. to Engineer) Nov. 1927, pp. 164-165.

HARDENED. On the Constitution and Properties of Hardened Steel, W. P. Sykes

and Z. Jeffries. Am. Soc. Steel Treating—Trans., vol. 12, no. 6, Dec. 1927, pp. 871-898 and (discussion) 898-904. Investigation of changes in hardness of freshly quenched steel taking place at, above and below room temperature; capability of "age" hardening above zero degrees Cent. is not lost by previous hardening produced by cooling below zero degrees; in fact, "age" hardening at room and certain higher temperatures is greater after hardening by immersion in liquid oxygen; maximum Rockwell "C" hardness values obained on carbon steels were 70.1 on 1.23 per cent and 70.2 on 1.58 per cent carbon steel.

HIGH-GRADE. Results of Recent Research on Properties of High-Grade Steels (Neue Ergebnisse der Edelstahlforschung), W. Oertel. V. D. I. Zeit., vol. 71, no. 43, Oct. 22, 1927, pp. 1503-1509, 21 figs. Standardization and tests of steels in Germany and United States; treatment of structural, tool and swage steels; effect of hardening, annealing and testing temperatures on hardness and other mechanical properties of high-speed steels.

HIGH TEMPERATURES, EFFECT OF. Properties of Ferrous Metals at Elevated Temperatures as Determined by Short-Time Tensile and Expansion Tests, A. E. White and C. L. Clark. Am. Soc. Mech. Engrs.—advance paper for mtg., Dec. 5-8, 1927, 15 pp., 34 figs. Discusses properties of plain carbon steels and Enduro metal at elevated tempertures; short-time tensile and expansion tests were run on plain carbon steels of tubular stock containing 0.13 and 0.38 per cent carbon, and on Enduro, an alloy containing 16.70 per cent chrominum and 0.09 per cent carbon.

HIGH TEMPERATURES, EFFECT OF. Properties of Materials at High Temperatures, H. J. Tapsell and W. J. Clenshaw. Eng. Research—Special Report, no. 2, July 1927, 16 pp., 8 figs. Mechanical properties of 0.51 per cent carbon steel, and 0.53 per cent carbon cast steel. See abstract in metallurgist (supp. to engineer), Nov. 25, 1927, pp. 172-174.

INGOTS, REVERSED SEGREGATION. Reversed Segregation in Steel Ingots and Its Behavior Upon Working, F. Rapatz. Iron & Steel World, vol. 1, no 5, June 1927, pp. 327-330, 5 figs. Reversed segregation caused by cooling action of mold; cannot be removed by mechanical working, even through elongating to quite small cross sections; has no injurious effects upon behavior of steel in hardening and use. Translated from Stahl u. Eisen.

MECHANICAL PROPERTIES. Significance of Shearing Resistance and Cohesive Strength in Tests of Materials (Die Bedeutung des Gleit- und Reisswiderstandes für die Werkstoffprüfung), P. Ludwik. V. D. I. Zeit., vol. 71, no. 44, Oct. 29, 1927, pp. 1532-1538, 16 figs. That shearing resistance and cohesive strength are most important mechanical properties of elastic materials upon which all other forms of strength depend, is shown by review of studies of recent tests and experiments on hardness, tensile strength, impact strength, fatigue, aging, etc., of steels and alloys.

OXYGEN CONTENT. Role of Oxygen in Metallurgy and its Bearing on the Quality of Steel (Die Rolle des Sauerstoffes für die Metallurgie und die Qualität des Stahls), P. Oberhoffer and W. Hessenbruch and H. Esser. V. D. I. Zeit., vol. 71, no. 45, Nov. 5, 1927, pp. 1569-1576, 15 figs. History of oxygen problem; analytic determination of oxygen content and oxygen compounds; their effect on properties of steel; deoxidation of steel; experimental studies of process.

PROPERTIES AND STRUCTURE. The Relations Between the Properties of Materials and Their Structure, A. Pomp. Eng. Progress, vol. 8, no. 10, Oct. 1927, pp. 263-264, 2 figs. Points out that nature of structure is of great moment as regards machining of steel with cutting tools; original structure of steel is also of decisive importance for results obtained in hardening; influence of cementite structure on result of hardening; favorable results achieved with tempering.

QUALITY OF. Quality of Steel, History and Present Status of Problem (Entwicklung und Stand der Qualitätsfrage), P. Oberhoffer. Stahl u. Eisen, vol. 47, no. 37, Sept. 15, 1927, pp. 1512-1526, 14 figs. Historical review from Réaumur to Ledebur; judging quality of steel from chemical analyses, and difficulties involved oxygen in steel, its determination and significance; application of methods of physical chemistry, results and prospects.

ROLLED, CRYSTALLITE ORIENTATION. Changes in Orientation of Crystallites of Steel Due to Rolling (Ueber die Aenderung der Kristallitenorientierung beim Walzen des Eisens), G. Tammann and A. Heinzel. Zeit. für anorganische u. allgemeine Chemie, vol. 167, no. 1-2, Oct. 14, 1927, pp. 173-182, 6 figs. Laboratory study of ingot of low-carbon specimens steel rolled in 5 to 10 per cent and in 2 to 3 per cent passes; significance of rolling process.

STAINLESS. Stainless Steels (Ueber die nichtrostenden Stähle), B. Strauss. Zeit. für Elektrochemie, vol. 33, no. 8, Aug. 1927, pp. 317-321, 8 figs. History of development and their properties and applications; experiments on electrode potential of chromium steels; effect of annealing temperature on magnetic properties of chromium-nickel steels.

STAINLESS. Voltage Measurements of Stainless Steels (Potentialmessungen an nichtrostenden Stählen), H. Stäger and H. Zschokke. Zeit. für angewandte Chemie, vol. 40, no. 44, Nov. 3, 1927, pp. 1265-1270, 10 figs. Report from metallographic laboratory of Brown, Boveri Co., Baden, giving results of experiments of martensite steels containing from 13 to 27 per cent of chromium; review of recent theories and researches on passivity of metals.

TEMPER BRITTLENESS. The Temper Brittleness of Soft and Semi-Hard Steels (Ueber Glüh- und Anlass-Sprödigkeit weichen und halbharten Stahl), J. Feszczenko-Czopiwski. Zeit. des Oberschlesischen Berg- u. Hüttenmännischen Vereins zu Katowice, vol. 66, nos. 9 and 10, Sept. and Oct. 1927, pp. 548-555 and 624-638, 3 figs. Character of temper brittleness and methods of determining it; means of prevention; relation between stretching limit and Brinell hardness; properties governing expansion of material.

TEMPERATURE, EFFECT OF. Behavior of Steel at Low and at High Temperatures (Das Verhalten von Stahl bei tiefen und hohen Temperaturen), A. Pomp. V. D. I.

Zeit., vol. 71, no. 43, Oct. 22, 1927, pp. 1497-1502, 14 figs. Influence of time factor on static and dynamic tests at abnormal temperatures; review of work of French and Tuker of Bureau of Standards on life of steel at various degrees of loading; effect of temperature (range: 0 to 975 deg. Cent.) on hardness of tool steel, effect of low and high temperatures (range—70 to 500 deg.) on toughness of notched bars; tensile strength, toughness, elongation and contraction of 4 per cent silicon steel at temperatures ranging from 20 to 500 deg.

TESTING. Notes on the Spark Testing of Steel, G. M. Enos. Am. Soc. Steel Treating—Trans., vol. 12, no. 6, Dec. 1927, pp. 976-981. Sparks given off when ferrous materials are touched to rapidly revolving grinding wheel are characteristic of composition and type of iron or steel in question; author describes technique of making such test and spark characteristics typical of selected group of irons and steels.

STEEL CASTINGS

CUTTING. Cutting of Stainless Steel Castings, C. J. Holslag. Welding Engr., vol. 12, no. 10, Oct. 1927, p. 48, 1 fig. In general, as to electric welding, d.c. is best with copper-base rustless alloys, and a.c. for chrome and nickel-base alloys. See also Machy. (N. Y.), vol. 34, no. 4, Dec. 1927, p. 289.

DEVELOPMENTS. Developments in the Steel Castings Industry, R. D. Moore, vol. 37, no. 584, Oct. 27, 1927, pp. 63-64, 1 fig. Ingot viewed as a casting; how contraction operates; steel-propeller manufacture; making gear wheels; light intricate castings. Review of presidential address before Instn. Engrs. & Shipbldrs.

RISER CUTTING. Economies in Riser Cutting. Acetylene Jl., vol. 29, no. 5, Nov. 1927, pp. 191-192, 3 figs. Careful selection of jobs for cutting torch; separation of heavy and light cuts; study of proper gas pressures; proper shaping of heads for economical cutting.

WELDING. Welding Steel Castings, L. E. Everett. Foundry, vol. 55, no. 22, Nov. 15, 1927, pp. 898-899. Three processes are used to repair defective castings; selection of method depends on nature of defect and type of casting.

STEEL, HEAT TREATMENT OF

ANNEALING. Annealing of Hardened Steels with Special Reference to Low Temperature (Zur Frage des Anlassens gehärteten Stahls, unter besonderer Berücksichtigung tieferer Temperaturen), A. Merz and C. Pfannenschmidt. Zeit. für anorganische u. allegmeine Chemie, vol. 167, no. 3-4, Nov. 1, 1927, pp. 241-253, 7 figs. Compilation summarizing work of European, American and Japanese investigations; includes account of experiments on tempering with liquid air. Bibliograph.

AUTOMOBILE PARTS. Heat Treating 20,-000 Hubs and Piston Pins Daily, S. Thompson. Iron Trade Rev., vol. 81, no. 19, Nov. 10, 1927, pp. 1160-1161, 3 figs. Details of heat-treating department of Defiance Screw Machine Products Co.

DEFINITIONS AND FUNCTIONS. Some Facts About Heat Treatment, S. Dunn. Ry. Mech. Engr., vol. 101, no. 11, Nov. 1927, pp. 745-747. Definition; difference between iron and steel; function of heat treating; heat treating billets for forging, and in blacksmith shop; heating steel to critical temperatures; importance of accurate heat treatment.

ELECTRIC. Benefits Obtained from Electric Heat-Treatment. Elec. World, vol. 90, no. 19, Nov. 5, 1927, pp. 927-934. Annealing, carburizing, hardening and drawing in automatic electric furnaces speed up production in Detroit automobile plants; heat-treating costs reduced and quality improved.

HARDENING AND ANNEALING. Volume Changes in Steel Due to Hardening and Annealing (Volumenänderungen van Stahl beim Härten und Anlassen), W. Köhler. Centralblatt der Hütten u. Walzewerke, vol. 31, no. 43, Oct. 26, 1927, pp. 613-623, 31 figs. Phenomena of hardening and annealing, theories of steel hardening; report of series of experiments done at testing laboratories of Bergmann-Elektricitäts-Werke on changes in volume and length due to hardening and annealing of steels, cast steels and high-nickel steel.

HUMP METHOD. Hump Method of Heat Treatment. Indus. Australian & Min. Standard, vol. 78, no. 2014, Oct. 6, 1927, p. 373, 1 fig. "Hump" method was designed to meet as nearly as possible ideal hardening conditions; it gives clearly and by an unmistakable indication in form of a hump in curve of a recording instrument, time rather than temperature at which tool or part reaches its critical or change-point; quenching then takes place at a predetermined interval after hump appears, so that it and all subsequent operations rest upon solid foundation of exact knowledge as to interval between critical point and quench.

RIFLE BARRELS. Heat Treating Rifle Barrels of Stainless Steel, J. B. Nealey. Iron Trade Rev., vol. 81, no. 22, Dec. 1, 1927, pp. 1352-1354, 3 figs. Deals largely with gun-barrel manufacture and heat-treating operations.

TEMPERING. Tempering Processes in Quench-Hardened Carbon Steels (Längenänderungen von gehärteten Kohlenstoffstählen beim Anlassen), L. Traeger. Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, no. 294, 1927, pp. 1-20, 33 figs., and translated abstract in Mech. World, vol. 82, no. 2129, Oct. 21, p. 308. Review of earlier literature and report on original experiments concerning changes in volume, linear extension, mechanical strength, electrical resistance, solubility, etc. with increase in temperature; to conform with phenomena observed author suggests theory that steel, in passing from a metastable to a stable condition, tends to concentrate its carbon content, and that change at 100 deg. Cent. is due to breaking down of martensite.

STEEL INDUSTRY

AMERICA. The Economic and Social Development of the American Iron and Steel Industry, T. W. Robinson. Foundry Trade Jl., vol. 37, no. 585, Nov. 3, 1927, pp. 83-86. Influence of Bessemer's invention; dawn of twentieth century; production of iron and steel; power installation; wages and

their relation to living cost; increase in steel capacity; management and labor.

ELECTRIC HEAT IN. Electric Heat in the Iron and Steel Industry (Elektrowärme in der Eisenindustrie), G. Bulle. Stahl u. Eisen, vol. 47, no. 41, Oct. 13, 1927, pp. 1693-1694. Technical possibilities; advantages of electric over other furnaces; factors governing installation of electric furnaces.

TECHNOLOGICAL PROBLEMS. Technological Problems of the Steel Industry, W. A. Forbes. Am. Iron & Steel Inst.—Advance Paper for mtg., Oct. 28, 1927, 89 pp., 4 figs., and abstract in Iron Age, vol. 120, no. 18, Nov. 3, 1927, pp. 1235-1236. Throws light upon some of numerous major problems which confront metallurgists, chemists and technicians, whose activities are primarily in province of ferrous metallurgy.

STEEL MANUFACTURE

SULPHUR AND OXYGEN, ACTION OF. Parallel Between Sulphur and Oxygen in Steel Metallurgy, H. D. Hibbard. Fuels & Furnaces, vol. 5, no. 11, Nov. 1927, pp. 1445-1447. Action of sulphur and oxygen in making steel.

THOMAS PROCESS. The Relation between the Slagging of Iron and Manganese in the Thomas Process (Die Beziehungen zwischen der Verschlackung des Eisens und des Mangans beim Thomasverfahren), E. Faust. Stahl u. Eisen, vol. 47, no. 44, Nov. 3, 1927, pp. 1871-1872. Account of tests to determine relations between oxidation (slagging) of manganese and iron.

STEEL WORKS

BELGIUM. Cockrill Works Over Century Old; Built Around a Bishop's Palace, V. Delport. Iron Trade Rev., vol. 81, no. 22, Dec. 1, 1927, pp. 1360-1361, 2 figs. Activities of firm today are divided into ten departments: coal mines and coke ovens; iron-ore mines and quarries; blast furnace plant; steel plant; foundries; forges; railroad rolling stock and projectiles; boiler shop and structural steelworks; machinery and ordnance and shipyards; firm runs its own fleet of cargo boats between Belgium and Great Britain; number of workmen employed is 12,000.

BOILER PLANTS. A Steel Mill Boiler Plant, D. L. Mekeel. Am. Iron & Steel Inst. —Advance paper, for mtg., Oct. 28, 1927, 14 pp., 9 figs. New boiler plant at South Mills of Aliquippa Works of Jones & Laughlin Steel Corp., Pittsburgh. See also Iron Age, vol. 120, no. 19, Nov. 10, 1927, p. 1303.

ELECTRIC EQUIPMENT. Electrical Equipment in Steel Works (Entwicklung der elektrotechnischen Einrichtungen auf Hüttenwerken), E. Courtin. Stahl u. Eisen, vol. 47, no. 46, Nov. 17, 1927, pp. 1941-1954, 16 figs. Power generation and distribution; high-speed and low-speed generators, switchboards, transmission system, transformer stations; rolling-mill drives; electric drives for forging presses; electric steel furnaces; annealing and heating furnaces.

ELECTRICITY IN. Application of Electricity in Metallurgical Works (Ausgewählte Kapitel aus dem Anwendungsgebiete der Elektrotechnik in Hüttenwerken), F. Müller. Stahl u. Eisen, vol. 47, no. 44, Nov. 3, 1927, pp. 1853-1867, 40 figs. Deals with current-generation and distribution installations; protective devices for generators and transformers; arrangement of distribution systems and their protection; short-circuit currents; converters and phase advances, electric cleaning of blast-furnace gas; rolling-mill drives and auxiliary drives; electric heat; works control by means of meters and recorders.

ENGLAND. The Works of William Beardmore & Co., Limited, Mossend Steel Works. Foundry Trade Jl., vol. 37, no. 584, Oct. 27, 1927, pp. 61-62. 3 figs. Details of melting shop, section mills, cogging mill, ball-finishing plant; power station; plate mill; shearing plant, etc.

STRUCTURAL STEEL

SHIP CONSTRUCTION. High-Grade Steels for Ship Construction (Hochwertiger Konstruktionsstahl für den Schiffbau), C. Commentz. Werft—Reederei—Hafen, vol. 8, no. 19, Oct. 7, 1927, pp. 388-390. Reviews properties of British high-elastic steel, German St. 48 and silica steel (F-stahl), pointing out importance of strength at yield point; enumerates some of the advantages of using high grade steel in ship construction.

TEMPERATURE MEASUREMENT

FURNACES, CORRECTIONS. Correction of Temperature Measurements (Die Korrektur der durch Quarzlinse verursachten Fehler bei der Temperaturmessung), L. Duckwitz. Centralblatt der Hütten u. Walzwerke, vol. 31, no. 42, Oct. 19, 1927, pp. 603-605, 6 figs. Experimental study, done at mining and electro-metallurgical institute of Freiberg Mining Academy, to determine correction of errors due to quartz lens covering aperture of high temperature furnaces; correction graphs for readings with ardometer and optical pyrometer, for range of 700 to 1700 deg. Cent.

TIN

PRODUCTION, PROPERTIES AND USES. Tin: A Review. Foundry Trade Jl., vol. 37, no. 586, Nov. 10, 1927, pp. 97-101, 5 figs. Treating of its history; occurrence; mining; smelting; properties; uses; reclamation; and future.

WELDING

AIRCRAFT. Aircraft Welding Rigidly Inspected, R. K. Doran. Welding Engr., vol. 12, no. 10, Oct. 1927, pp. 32-33, 5 figs. Study of welding organization in Consolidated Aircraft Corporation plant, Buffalo, New York.

FUSION. Fusion Welding on Boilers and Pressure Vessels, S. W. Miller. Boiler Maker, vol. 22, no. 11, Nov. 1927, pp. 319-321. Tests developed to insure good welds; suggestions for inspectors to follow in acquiring knowledge of welding processes.

CAST IRON. The Welding of Cast Iron, P. L. Roberts. Mech. World, vol. 82, no. 2130, Oct. 28, 1927, pp. 329-330. Expansion and contraction during and after welding have to be very carefully considered: for this purpose castings are classed into three groups: free, semi-rigid, and rigid. Abstract of paper read before Instn. of Welding Engrs.

METHODS. Electric and Autogenous Welding of Structures (Ueber elektrisch und autogen geschweisste Konstruktionen), Eidgenossische Materialprufungsanstalt an der E. T. H. in Zurich, no. 12, June 1926, 46 pp., 112 figs. Contains articles with above title, by E. Höhn, and A. Sonderegger, article, by H. Frölich, entitled, Electric Welding in Bridge Erection, and discussion.

MOTOR FRAMES. Welded Steel for Motor Frames, K. F. Rauderbaugh. Iron Age, vol. 120, no. 22, Dec. 1, 1927, pp. 1507-1508 and 1567, 3 figs. History of application to induction motors; findings in costs of material, labor, inventory, toolroom expense and overhead.

PIPING. Welded Piping for Every Purpose. Welding Engr., vol. 12, no. 10, Oct. 1927, pp. 39-41, 5 figs. Elimination of mechanical joints result in economy of installation, increased efficiency and longer life for pipe installations.

RAILWAY CARS. The Use of Welding in Car Construction, V. R. Willoughby. Am. Welding Soc.—Jl., vol. 6, no. 9, Sept. 1927, pp. 11-24, 5 figs. Arguments for welded construction of railway cars; consideration of objections; comparison with riveted construction.

STEEL PLATE. Welding in the Design of Steel Plate Work, L. J. Sforzini. Am. Welding Soc.—Jl., vol. 6, no. 9, Sept. 1927, pp. 77-95, 11 figs. Dicussion of riveting and fusion welding of steel plates; brief consideration of other processes.

STRUCTURAL FORM, EFFECT ON. Effect of Welding Upon Structural Form (Einfluss des Schweissens auf die Gestaltung), A. Hilpert. V. D. I. Zeit., vol. 71, no. 42, Oct. 15, 1927, pp. 1449-1458, 99 figs. Principal welding methods and their characteristics; substituting oxyacetylene or arc welding for riveting, flange connections and monolithic casting and modifications in structural form resulting therefrom; cites number of examples showing effect of welding on shape of bridge girders, steel tanks, steel towers, pipe joints, dynamo housings, etc.

WELDS

METALLURGY OF. Some Metallurgical Observations on Welding, G. R. Brophy. Am. Welding Soc.—Jl., vol. 6, no. 9, Sept. 1927, pp. 67-76, 21 figs. Metallurgical aspects of welding and choice of materials used; bare and coated electrodes; plate stock; metallographic structure of welds; gas shields.

TESTING. Testing Welds by Means of Magnetic Spectrum (Controle des soudures par les spectres magnétiques), L. Roux. Académie des Sciences—Comptes Rendus, vol. 185, no. 17, Oct. 24, 1927, pp. 859-861, 4 figs. Tests showing practical nature of magnetic spectrum method.

WIRE

ANNEALING. Annealing of Metallic Wires (Glühversuche mit verschiedenen Metalldrähten), P. Siebe. Zeit für Metallkunde, vol. 19, no. 10, Oct. 1927, pp. 385-389, 6 figs. Experiments on salt bath annealing of wires made of electrolytic copper, refined copper, bronze, brass, aluminum and iron; effect of annealing temperature on decrease in tensile strength, shortest annealing period required to reduce tensile strength.

HARD-DRAWN. The Texture of Hard-Drawn Wires (Ueber die Textur hartgezogener Drähte), E. Schmid and G. Wassermann. Zeit. für Physik, vol. 42, no. 11-12, May 16, 1927, pp. 779-794, 24 figs. Results of X-ray analysis show for aluminum, copper, gold and silver, percentage of fragments which line up in two directions; by same method, authors found that fibers at center of wire are parallel to axis, while just beneath surface they are tilted to axis at same angle as that of die used in drawing.

TESTING. Substituting the Ball-Pressure Test for Tension and Torsion Tests (Ersatz der Zug- und Torsionsfestigkeitsprüfung von Eisen- und Stahldrähten durch Kugeleindrücke), B. Garre. Centralblatt der Hütten u. Walzwerke, vol. 31, no. 30, Sept. 28, 1927, pp. 557-559, 6 figs. Experimental study done at Danzig Technological Institute, showing that in testing iron and steel wires, tensile and torsional strength may be determined with sufficient accuracy from a ball-pressure test there being a slight line function of latter.

WIRE DRAWING

PLANTS. Rod-Rolling and Wire-Drawing, J. P. Bedson and J. S. G. Primrose. Iron & Coal Trades Rev., vol. 115, no. 3104, Aug. 26, 1927, pp. 289-292, 5 figs. Methods at Bradford Iron Works in Manchester, England; plant layout, continuous rod mills, processes. Paper read before West of Scotland Iron & Steel Inst. and printed in "Journal" of Inst.

X-RAYS

INDUSTRIAL USES OF. Use of X-Rays in Shops and in Industrial Laboratories (Les services que peuvent rendre les rayons X dans les ateliers et dans les laboratoires industriels), M. A. Laborde. Electricité & Mecanique, no. 19, July-Aug., 1927, pp. 25-38, 17 figs. Use of X-rays in metallographic, and crystallographic studies, in detecting flaws in metallic parts, welds, alloys, etc., in studying internal structure of alloys, metals, textile fibers, rubber goods etc.; use of high-frequency spectrography in study of chemical compounds, particularly in detecting rare earths.

MATERIALS-STRUCTURE ANALYSIS. X-rays and the Crystalline Structure of Materials, W. H. Bragg. Engineer, vol. 144, no. 3748, Nov. 11, 1927, pp. 534-535. Fundamental principles of new method of examining structures of nature: its importance lies in its application to range of dimensions where properties of structures are mainly formed.

METAL-STRUCTURE ANALYSIS. X-Ray Analysis of Metals, W. H. Bragg. Engineering, vol. 124, no. 3226, Nov. 11, 1927, pp. 627-629, 18 figs. Sketch of principles on which new method of analysis was based, choosing illustration mainly from materials employed by mechanical engineers; methods in question were employed both in pure and applied science, and were concerned with fine structure of materials.

News of the Society

SUMMARY OF RECOMMENDED PRACTICE COMMITTEE MEETING
Held in the National Office of the A. S. S. T., Cleveland, Nov. 16, 1927

Members Present: Messrs. W. J. Merten, chairman, G. H. Wright, P. C. Osterman, F. C. Langenberg, J. H. Gibboney, R. S. Archer, J. E. Donnellan.

Absent: Messrs. J. A. Mathews and H. M. Northrup.

Guests Present: Messrs. J. R. Paige, H. M. Boylston and R. T. Bayless.

(1) About a year ago the subcommittee on the Mechanism of Cementation was assigned, by the Recommended Practice Committee, the problem of preparing a practice on the nitrogenizing of steel. The committee endeavored to prepare a suitable report on this subject, but it was found impossible to carry out this problem to completion because the subject was assigned to the sub-committee before standard data were available. The sub-committee on the Mechanism of Cementation was, therefore, reorganized and assigned a more appropriate problem.

The Recommended Practice Committee believes that the present problem of preparing a practice on the mechanism of cementation when using solid, liquid, and gaseous compounds is of more immediate importance.

The personnel of the sub-committee on the Mechanism of Cementation is as follows: V. N. Krivobok, chairman, W. B. Crowe, W. I. McInerney, N. S. Ihsen and C. H. Herty, Jr.

(2) The sub-committee for the Heat Treatment of Water and Oil Hardening Gears recently held a meeting, at which time the sub-committee decided that it was not advisable to incorporate in the practice information and heat treatments for the plain carbon steel, inasmuch as the subcommittee was composed of men familiar with only the alloy steels. The sub-committee, therefore, recommended to the Recommended Practice Committee that they consider the report as pertaining only to alloy steels and that a new sub-committee be appointed to prepare a practice on carbon steel gears.

The Recommended Practice Committee agreed that a sub-committee for the Heat Treatment of Carbon Steel Gears should be appointed. It was, therefore, decided that J. M. Darke, of the General Electric Company, Lynn, Mass., be appointed chairman of the sub-committee. Mr. Darke has the privilege of selecting the members for this sub-committee.

(3) Dr. V. O. Homerberg, of the Massachusetts Institute of Technology, submitted to the Recommended Practice Committee the suggestion of appointing a sub-committee to prepare a report on Deep Acid Etching. The Recommended Practice Committee approved of appointing this sub-committee and recommended the appointment of Dr. Homerberg as chairman. Dr. Homerberg has the privilege of selecting his own personnel.

(4) Inasmuch as the present data sheets on Etching Solutions for Iron and Steel, papes T-7 to T-22 of the A. S. S. T. HANDBCOK, contain solutions for deep acid etching, it was decided to appoint a sub-committee to revise these sheets, eliminating all the deep acid etching solutions. In addition to eliminating the deep etching solutions, the solutions for microscopic examination should be revised and brought up to date.

Prof. H. M. Boylston, of the Case School of Applied Science, was recommended as the chairman of this sub-committee. Prof. Boylston has the privilege of selecting his own personnel.

(5) In order to develop closer co-operation between the Recommended Practice Committee and the chapters, as well as to increase the activities of the technical committees, the secretary was instructed to write the executive committees of those chapters which do not have a sub-committee in their city for a suggestion of a specific problem for sub-committee work. These problems will then be submitted to the Recommended Practice Committee and steps will be taken to appoint within the chapters from which the suggestions came, sub-committees to work on the suggested problems.

(6) It was decided to take up with the Springfield chapter the appointment of a sub-committee to prepare a practice for the heat treatment and coloring of guns and gun parts. The coloring may be covered satisfactorily in the data sheets that are already published in the HANDBOOK on pages A 91-A 97. This phase of the problem, however, can be considered by the sub-committee and if the information on coloring is satisfactory, references to the coloring processes can be made in the heat treating practice.

(7) J. R. Adams, chairman of the Philadelphia chapter, invited the Recommended Practice Committee to assign a problem to a sub-committee composed of members of the Philadelphia chapter. It was, therefore, decided by the Recommended Practice Committee that the Philadelphia chapter suggest the personnel for a sub-committee to prepare a practice on the manufacture and heat treatment of ship, crane, and bridge cable, including the care of the cable, splicing, etc.

(8) The Executive Committee of the Worcester chapter is to be invited to suggest the personnel for a sub-committee to prepare a practice on the cold drawing process.

(9) Frank Speller, of the National Tube Company, Pittsburgh, is to be appointed chairman of a sub-committee to prepare data sheets on the manufacture of iron and steel tubes. The sheets are to include information on seamless tubes, such as piercing, drawing, straightening, etc., and also to cover the manufacture of lap and butt welded tubes.

(10) A sub-committee is to be appointed on the manufacture and heat treatment of roll crushers, jaws, etc. J. Fletcher Harper is to be invited to suggest a personnel for this sub-committee from the Milwaukee chapter.

(11) The executive committee of the New York chapter is to be

invited to suggest a personnel for a sub-committee to prepare a practice for the heat treatment of needles and pivot points for instruments.

(12) A. E. Buelow, of the Lamson-Sessions Co., Cleveland, is to be appointed chairman of a sub-committee to prepare a practice on cold heading, roll threading, and the heat treatment of bolts. Mr. Buelow has the privilege of selecting the personnel for this sub-committee.

(13) Dr. Geo. L. Kelley, of Philadelphia, is to be appointed chairman of a sub-committee to prepare data sheets on cold forming and stamping. Dr. Kelley has the privilege of selecting the personnel for this sub-committee, but the Recommended Practice Committee suggested that representatives of the automotive and steel industries might be selected as some of the members for the sub-committee.

(14) The Recommended Practice Committee received from Prof. Boylston, chairman of the A. S. T. M. Committee, A-4, a proposal to form a joint committee or to work out a co-operative arrangement with the A. S. T. M. in preparing recommended practices for the heat treatment of steel castings. There appeared, however, to be a misunderstanding between the two organizations inasmuch as a co-operative arrangement did exist through Dr. A. E. White, chairman of the A. S. T. M. Carbon Steel Castings Committee, and the A. S. S. T. Steel Castings Committee. As this representation gives both committees the benefit of experiences and accomplishments of each organization, the Recommended Practice Committee decided that it was not advisable to organize a joint committee, which would naturally increase the size of the sub-committee and cause the work to progress more slowly than is necessary or advisable.

As the A. S. S. T. Steel Castings sub-committee is now working on a practice for the heat treatment of alloy castings, it was decided to invite the A. S. T. M. to appoint another representative from their alloy castings committee.

(15) It was decided to publish in data sheet form the hardness conversion chart which was submitted to the committee by the Chicago chapter.

(16) The tentative recommended practice for the Heat Treatment and Care of Sling and Crane Chain was approved for publication in the A. S. S. T. HANDBOOK. Inasmuch as the sub-committee on Chain has therefore completed its work it was decided to discharge the sub-committee from active duty.

(17) E. L. Reed, of Boston, will prepare data sheets giving photomicrographs of the various constituents found in steel. In addition to the photomicrographs sufficient text matter is to be included to explain the general characteristics of each constituent.

(18) In order to be in a position to assist the Nonferrous Data Sheet Committee and to be more familiar with work in process of preparation, the Recommended Practice Committee felt it advisable to submit the nonferrous data sheet manuscript to the Recommended Practice Committee at the same time the manuscripts are submitted to the Nonferrous Data Sheet Committee. *J. Edward Donnellan, secretary.*

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, SATURDAY, DECEMBER 10, 1927

A. S. S. T. HEADQUARTERS, CLEVELAND

Officers Present: Messrs. J. F. Harper, F. G. Hughes, Dr. Zay Jeffries, J. M. Watson, W. H. Eisenman, R. G. Guthrie, Hyman Bornstein, L. D. Hawkridge, J. H. Nead, W. H. Phillips, T. E. Barker.

Absent: R. M. Bird.

Upon motion made by Mr. Bornstein, seconded by Mr. Hawkridge, and unanimously carried, the following resolution of organization was adopted:

"Resolved in order to comply with the laws of Ohio, in which the Directors of the Society elect their own officers, it is hereby resolved that the following officers be elected for the A. S. S. T. for 1928:

F. G. Hughes—President.
Zay Jeffries—Vice-President.
W. H. Eisenman—Secretary.
J. M. Watson—Treasurer.

The secretary then read the minutes of the previous meeting held at Hotel Statler, Detroit, on September 18, 1927; as well as the report of the Nominating Committee Meeting held at Hotel Statler, Detroit, on September 19, 1927; and the minutes of the Annual Meeting of the Society held in the Ballroom, Hotel Statler, Detroit, on September 21, 1927. Upon motion made and seconded, the minutes were approved as read.

Upon motion by Mr. Hawkridge, seconded by Mr. Nead, and unanimously carried, the following were appointed as members of the National Committees: (See pages 28 and 29 this issue of TRANSACTIONS).

The treasurer presented an unaudited financial statement with reference to the Detroit Exposition in 1927. This report was accepted and ordered filed.

The secretary presented a progress report on the 1928 exposition which is as follows:

1. Floor plan prepared for distribution the middle of January.
2. Total space available approximately 75,000 square feet. Total revenue possible and probable in case of a complete sell-out, \$79,000.00, or \$13,000.00 less than Detroit.

National Metal Week is again assured due to definite acceptance of co-operation from

(a) American Welding Society
(b) Institute of Metals
(c) Possible co-operation with A. S. M. E., Iron and Steel Division.

Selection of hotel headquarters.

Upon motion properly made, seconded and carried, the Benjamin Franklin Hotel was selected as headquarters for the Philadelphia Convention provided satisfactory arrangements could be made.

The secretary presented a report with reference to the proposed Western Metal Exposition, including a list of 68 firms that had indicated their willingness to co-operate if the Society held the proposed exposition; also a report

from 36 firms indicating that they desired to give the matter further consideration and would report later. There was also submitted to the Board an estimated budget of expenses for the exposition.

Upon motion by Mr. Hughes, seconded by Mr. Bornstein, and unanimously carried, it was voted that the Society should hold the Western Metal Exposition in Los Angeles providing satisfactory arrangements could be made.

It was moved by Mr. Bornstein, seconded by Mr. Nead, and unanimously carried, that the Semi-Annual Meeting of the Society for 1929 should be held in Los Angeles in January, 1929.

Upon motion properly made, seconded, and carried, the following schedule for the Semi-Annual Meeting to be held in Montreal, February 15, 16 and 17, was approved. (See page 177 January TRANSACTIONS.)

The secretary then presented a report on engineering extension, particularly the work that had been done by Professor Keller in the two groups of cities at which his course has been given.

The cities of Canton-Massillon, Columbus, Dayton, Erie and Youngstown with an enrollment of 355 constituted the first group. The cities of Chicago, Milwaukee, Rockford, South Chicago and Tri-City with an enrollment of 841 constituted the second group.

Mr. Keller returns to Purdue University on January 1, 1928. His lectures have been recorded by stenotype for use next year in book form for distribution to classes in case he is again with the A. S. S. T.

A report on the location of the Convention city for 1929 was then presented. It was the sentiment of the Board that the 1929 Exposition should be held in a Western city if possible, and the preferences of the Board as expressed were for either Chicago or Milwaukee. The secretary was instructed to secure additional information with reference to these two cities and submit it to the Board at their next regular meeting in Montreal in February.

Upon motion by Mr. Hughes, seconded by Mr. Watson, and unanimously carried, the following were authorized to sign checks for the disbursement of funds of the A. S. S. T.: J. M. Watson, treasurer; W. H. Eisenman, secretary; Zay Jeffries, member Finance Committee; J. B. Dillard, member Finance Committee; and the secretary was authorized to notify the Cleveland Trust Company to that effect.

Upon motion made by Dr. Jeffries, seconded by Mr. Hughes, and unanimously carried, the Board authorized the investment of $30,000.00 surplus in suitable high grade bonds.

Upon motion made by Mr. Bornstein, seconded by Dr. Jeffries, and unanimously carried, it was voted that an appropriation of $5000.00 be used in the purchase of new furniture and equipment for the National Office.

Upon motion by Dr. Jeffries, seconded by Mr. Bornstein, and unanimously carried, the amount of $75.00 was authorized as a contribution to the memorial stone being placed on the grave of late Founder Member Arthur G. Henry, by the Chicago Chapter.

Upon motion properly made, seconded and carried, the meeting adjourned at 5:00 P. M.

Respectfully submitted, *W. H. Eisenman, secretary.*

SEMI-ANNUAL MEETING IN MONTREAL

Mt. Royal Hotel, February 15, 16 and 17, 1928

In the December issue of TRANSACTIONS, page 1005, was published the tentative technical program to be presented at the Semi-Annual Meeting of the Society in Montreal, Quebec, February 15, 16 and 17, 1928. While the order of the presentation of technical papers has not been definitely arranged the following outline of events will be adhered to. This will be the first semi-annual meeting held by the society, and an unusually large attendance is expected. For those who have not as yet made their hotel reservations it is suggested that they immediately communicate with the management of the Mount Royal Hotel indicating the type of accommodations they desire.

A complete program of technical papers and the time of their presentation will be published in the February issue of TRANSACTIONS.

WEDNESDAY, FEBRUARY 15

9:30 A. M.—Meeting of Board of Directors.
Meeting of Publication Committee.
Meeting of Recommended Practice Committee.
6:00 P. M.—Early Birds' Dinner. Special tables in Main Dining Room.
7:30 P. M.—Option of tobogganing or theatre party.
Special cards of admission for the Toboggan.
Special cards of admission for the Toboggan Club will be sold at the Early Birds' Dinner.

THURSDAY, FEBRUARY 16

9:30 A. M.—Technical session. Piazza Room, Ninth Floor.
2:00 P. M.—Technical Session. Piazza Room, Ninth Floor.
6:30 P. M.—Dinner. Special tables in Main Dining Room.
Technical session following. Piazza Room, Ninth Floor.

FRIDAY, FEBRUARY 17

9:30 A. M.—Technical session. Piazza Room, Ninth Floor.
1:30 P. M.—Choice of Plant Inspection:
(1) Canadian Steel Foundries, Longe Pointe Plant, manufacturing locomotive frames, railroad castings and hydro-electric castings; and McVickers, Ltd., the largest Canadian producers of airplanes.
(2) Dominion Engineering Works, Ltd., and Dominion Iron Works, Ltd., manufacturing largest paper machinery on this continent; also oil stills, tank work and some heavy construction work.
6:30 P. M.—Dinner. Special tables in Main Dining Room.
Technical session following. Piazza Room, Ninth Floor.

SATURDAY, FEBRUARY 18

Afternoon —Province of Quebec Champion Ski Jumping by Montreal Ski Club at the Cote des Neiges hill. Admission by special badge which can be procured at headquarters.
Evening —Professional hockey game between Detroit and Montreal Maroons. This is from the big hockey league.

News of the Chapters

SCHEDULED MEETING NIGHTS OF CHAPTERS

For the convenience of visiting members, those chapters having scheduled meeting nights are listed below.

BOSTON—First Friday. H. E. Handy, secy., Saco-Lowell Shops, Lowell, Mass. Phone Lowell 4050.

Jan. 6—Testing Machines .... I. H. Cowdrey
Feb. 3—Methods of Constructing the Alloy Diagrams .... R. S. Williams
Mar. 2—Hardening and Tempering of Steels .... R. S. Williams
Apr. 6—Pyrometry .... V. O. Homerberg
May 4—Stainless Iron and Stainless Steel .... V. O. Homerberg

BUFFALO—Fourth Friday, with exception of Dec. 15 and Jan. 26. F. L. Weaver, secy., American Radiator Co., Bond Plant. Phone, Riverside 1770.

CANTON-MASSILLON—No schedule of meetings as yet received. Robt. Sergeson, secy., Central Alloy Steel Corp., Canton, Ohio. Phone 5121.

CASE GROUP—No schedule of meetings as yet received. J. M. Burns, secy., Case School of Applied Science, Cleveland. Phone, Garfield 6680.

CHICAGO—Second Thursday, with exception of March 6. J. A. Comstock, secy., Room 1724 Peoples Gas Bldg. Phone, Wabash 6000, Local 364.

Jan. 12—Chromium Plating .... H. E. Haring
Feb. 9—Pyrometry and Its Application .... G. S. Gordon
Mar. 6—Nickel Cast Iron .... P. D. Merica
Apr. 12—Manufacture of Cold Drawn Steel .... F. R. Bonte

CINCINNATI—No schedule of meetings as yet received. W. J. Lange, secy., Robert J. Anderson, Inc.

CLEVELAND—Third Friday. J. S. Ayling, secy., Case Hardening Service Co. Phone, Atlantic 0293.

Jan. 20—Aircraft .... H. C. Knerr
Feb. 17—Cap Screws .... Tom Ferry
Mar. 16—Brass and Bronze Alloy .... C. H. Bierbaum
Apr. 20—Metal Stamping .... G. L. Kelley
May 18—Social Meeting.

COLUMBUS—Third Tuesday, with exception of Feb. 14. G. D. Moessner, secy., Buckeye Steel Castings Co. Phone, Garfield 0600.

Jan. 17—Hardening of Steel and Effect of Size and Shape ...... O. Z. Klopsch
Feb. 14—Fuels and Furnaces .... H. J. N. Voltmann
Mar. 20—High Speed Steels .... J. V. Emmons
Apr. 17—Forgings .... Harold Wood
May 15—Open-Hearth Practice .... W. R. Flemming

DAYTON—No schedule of meetings as yet received. F. M. Reiter, secy., Dayton Power & Light Co.

DETROIT—Third Monday. Jos. G. Gagnon, secy., Hudson Motor Car Co. Phone, Lenox 3232.

FORT WAYNE—Paul Renfrew, secy., S. F. Bowser & Co., Phone, Harrison 2341.

January —Dilatometric System of Heat Treating .... S. P. Rockwell
February—Procedure of Correct Hardening .... Jordan Korp
March —Carburizing and Heat Treatment .... B. F. Shepherd
April —Nickel-Chromium Alloy in Gray Iron .... D. M. Houston
May —Shop Equipment and Shop Kinks .... H. B. Northrup

GOLDEN GATE—Second Wednesday. S. R. Thurston, secy., Bethlehem Shipbuilding Corp., San Francisco.

Jan. 11—Heat Treatment of Ordnance Material .... Major T. J. Hayes
Feb. 8—Stanford University Visit
The Relation Between Cutting Power of Metals and Their Heat Treatment .... A. B. Domonoske
History of the Development of the Use of Metals ..... T. J. Hoover

Mar. 14—Symposium and Discussion by Members on the Physical Properties of Steel. Their Significance and Their Relations. Bases for the Selection of Carbon and Alloy Structural Steels for Specific Purposes.
Apr. 11—Joint Meeting with the American Welding Society—Subjects:
Properties of Welds at High Temperatures.........K. V. Laird
Properties of Carbon and Alloy Steels at High Temperatures.
May 9—The Hardness of Metals, Methods of Testing and What They Test. Comparison of the Wear Resistance of Different Metals Under Different Conditions of Heat Treatment.
June 13—Heat Treatments of Nonferrous Alloys, Their Purpose and Their Significance.
Moving Picture—The Story of Copper.

HARTFORD—Second Tuesday. Henry I. Moore, secy., Firth Sterling Steel Co. Phone, 6-5554 Hartford.

Jan. 10—New Developments in Stainless Steels at Home and Abroad.... ....G. J. Comstock
Feb. 14—Ask Me Another—Speakers, Anyone with a Question.
Mar. 13—Heat Treatment of Aluminum Alloys................R. S. Archer
Apr. 10—Manufacture of Automotive Alloy Steels..............E. C. Smith
May 8—Manufacture of Malleable Iron....................H. A. Schwartz
June 8—Eighth Annual Banquet.

INDIANAPOLIS—Second Monday. James S. Marlowe, secy., 606 State Life Bldg. Phone Riley 3724.

LEHIGH VALLEY—No schedule of meetings as yet received. H. V. Apgar, secy., Ingersoll-Rand Co., Phillipsburg, N. J. Phone 977.

LOS ANGELES—Second Thursday. H. V. Ruth, secy., Ducommun Corp. Phone TR. 0621.

MILWAUKEE—Second Monday. Knight Charlton, secy., Bucyrus Co. Phone 1.

MONTREAL—No schedule of meetings as yet received. D. G. MacInnes, secy., Apt. 35, 376 Claremont Ave., Westmount, Montreal.

NEW HAVEN—Second Thursday, with the exception of Dec. 15, Jan. 11, and June 15. F. E. Stockwell, secy., Standard Oil Co. of New York. Phone, Beacon 1520, Pioneer 9940.

NEW YORK—Second Monday. I. N. Holden, Jr., secy., E. W. Bliss Co. Phone, Sunset 9000.

NORTH-WEST—No schedule of meetings as yet received. Alexis Caswell, secy., Manufacturers' Assn. of Minneapolis.

Jan. —Gas and Gas Carburizing........................R. G. Guthrie
Feb. —Nitralloy..R. P. DeVries
Mar. —Open
Apr. —Molybdenum Steels.......................Dr. F. C. Langenberg
May —Gears and Gear Steel.................................E. C. Smith

NOTRE DAME—Second Friday, with exception of December 8. Frank J. Mootz, secy., Notre Dame University. Phone, Lincoln 1121.

PHILADELPHIA—Last Friday. A. W. F. Green, secy., 407 Shoemaker Rd., Elkins Park, Pa. Phone, Melrose 4542-M.

Jan. 6—No subject reported
Jan. 27—Application of X-Rays to the Commercial Inspection of Metals
Feb. 24—Nonferrous Metallurgy
Mar. 30—Case Hardenings with Particular Attention to Nitrogenizing
Apr. 27—General Melting Practice, Influence of Crystallization and Cooling on the Commercial Application of Metals.

PITTSBURGH—No schedule of meetings as yet received. H. L. Walker, secy., Box 521, North Side Station.

RHODE ISLAND—Third Wednesday. C. G. Peterson, secy., 100 Weybosset St., Providence. Phone, Gaspee 6233.

ROCHESTER—Second Monday. Irving C. Mathews, secy., Eastman Kodak Co. Phone, Glenwood 1300.

Jan. 9—Malleable Iron ....Enrique Touceda
Feb. 13—Testing ....T. Y. Olsen
Mar. 12—Dr. Jekyl and Mr. Hyde of Metallurgy................T. S. Fuller

Apr. 9—Die Castings .... Sam Tour
May 14—Business Meeting—Election of Officers

ROCKFORD—Second Friday, with exception of Jan. 12. O. T. Muehlemeyer, secy., 700-702 Race St. Phone, Forest 447.

SCHENECTADY—Third Tuesday. J. G. Hicks, sec., American Locomotive Co. Phone, 2-4900-Ext 44.

Jan. 17—Magnetic Analysis, Particularly as Applied to High Speed and other Steels.......................................A. V. deForest
Feb. 21—Machinability and Machining Problems of Nickel Steels and Ordinary Cast Iron, Monel Metal, etc............T. H. Wickenden
Mar. 20—Steels at Elevated Temperatures.........H. J. French, F. B. Foley

SOUTHERN TIER—Third Monday, with exception of Apr. 23. Walter H. Ogden, secy., 11 Rotary Ave., Binghamton, N. Y. Phone, Bingham 2425.

SPRINGFIELD—Third Monday, with exception of Mar. 21, Apr. 25 and May 23. E. L. Woods, secy., Springfield Gas Light Co. Phone, 5-3900.

ST. LOUIS—Third Friday. C. G. Werscheid, secy., Colonial Steel Co. Phone, Garfield 1263.

SYRACUSE—Second Tuesday. S. P. Peskowitz, secy., Halcomb Steel Co. Phone, 3-1231.

Jan. 10—Automobile Design and Automotive Steels.......T. H. Wickenden
Feb. 14—Some Phases of the Iron and Steel Industries........W. W. Macon
Mar. 13—Carburizing and Heat Treatment of Carburized Objects..B. F. Shepherd
Apr. 10—Flow of Metals in Forging........................J. H. Nelson

TORONTO—No schedule of meetings as yet received. Campbell Bradshaw, secy., 153 University Ave.

TRI CITY—No schedule of meetings as yet received. George A. Uhlmeyer, secy., People's Power Co., Moline, Ill.

WASHINGTON-BALTIMORE—No schedule of meetings as yet received. H. K. Herschman, secy., Bureau of Standards.

WORCESTER—Dec. 9, Jan. 6, Feb. 3 and Mar. 14—no further meeting dates as yet scheduled. C. G. Johnson, secy., Worcester Polytechnic Institute. Phone, P110.

STANDING OF THE CHAPTERS

DURING the month of November there were 134 new and reinstated members, while 82 were lost through arrears, resignations and deaths, leaving a net gain for the month of 52 members. The total membership of the Society on December 1, 1927, was 4861.

Membership standing of the society as of December 1, 1927, is as follows:

GROUP I.—Detroit heads the list, being the first chapter in the Society ever attaining a membership of over 500. Detroit is to be congratulated on the splendid progress they have made during the last year. Chicago, Pittsburgh and Philadelphia suffered a loss as compared with last month, while Cleveland, Boston and New York showed slight gains.

GROUP II—This group is still headed by Dayton although Hartford with a gain of 3 enters into a tie with the new chapter for position No. 1. Next month should show some interesting developments with reference to the honor for heading Group II. Golden Gate with a gain of 5 members advanced from position 6 to 5, displacing Canton-Massillon from the fifth position. The other chapters in this group retained the same position as last month.

GROUP III—Tri City and Los Angeles are in an interesting endeavor to

head up this group. Tri City has been there for some time but Los Angeles is gradually coming up and at the present time is only one member behind the leader. Los Angeles showed the largest gain in membership in this group with 5, while Tri City was second with a gain of 4. Last month Southern Tier had position 6 while this month they are in 8. Rockford advanced from 8th place to 6th.

GROUP I		GROUP II		GROUP III	
1. Detroit	503	1. Dayton	132	1. Tri City	90
2. Chicago	432	2. Hartford	132	2. Los Angeles	89
3. Pittsburgh	350	3. Milwaukee	124	3. New Haven	81
4. Philadelphia	335	4. Lehigh Valley	117	4. Worcester	76
5. Cleveland	311	5. Golden Gate	113	5. Washington	72
6. New York	297	6. Canton-Massillon	112	6. Rockford	63
7. Boston	253	7. Indianapolis	98	7. Rochester	62
		8. Cincinnati	95	8. Southern Tier	61
		9. St. Louis	91	9. Columbus	58
		10. Syracuse	88	10. Toronto	56
		11. Montreal	72	11. Providence	54
		12. Buffalo	68	12. Ft. Wayne	42
		13. North-West		13. Schenectady	42
				14. Springfield	34
				15. Notre Dame	26

Analysis of Membership Standing During 1927

Many members of the society are intimately interested in the statis of other chapters in respect to their own and with this in mind we are publishing some interesting statistics relative to the losses and gains of all of the chapters of the society.

Table I gives the total membership of each chapter and group as of November 30, 1927, and the membership a year ago, November 30, 1926, showing the net gain or loss of the chapter in members, and also the percentage of gain or loss for that chapter.

Table I

	11/30/27	11/30/26	Gain or Loss	% Gain or Loss
GROUP I				
Detroit	503	377	125 Gain	33.7 Gain
Chicago	432	380	52 Gain	13.7 Gain
Pittsburgh	350	320	30 Gain	9.4 Gain
Philadelphia	335	352	17 Loss	4.8 Loss
Cleveland	311	403	92 Loss	22.8 Loss
New York	297	268	29 Gain	10.8 Gain
Boston	253	242	11 Gain	4.6 Gain
GROUP II				
Dayton	132		132 Gain	Gain
Hartford	132	135	3 Loss	2.2 Loss

Milwaukee	124	128	4 Loss	3.1 Loss
Lehigh Valley	117	137	20 Loss	14.6 Loss
Golden Gate	113	117	4 Loss	3.4 Loss
Canton-Massillon	112		112 Gain	Gain
Indianapolis	98	84	14 Gain	16.7 Gain
Cincinnati	95	95	0	0
St. Louis	91	83	8 Gain	9.7 Gain
Syracuse	88	95	7 Loss	7.4 Loss
Montreal	72	83	11 Loss	13.2 Loss
Buffalo	68	59	9 Loss	15.3 Gain
North-West	52	55	3 Loss	5.5 Loss
		GROUP III		
Tri City	90	65	25 Gain	38.5 Gain
Los Angeles	89	73	16 Gain	22. Gain
New Haven	81	71	10 Gain	14.1 Gain
Worcester	76	59	17 Gain	28.8 Gain
Washington	72	68	4 Gain	5.9 Gain
Rockford	63	65	2 Loss	3.1 Loss
Rochester	62	64	2 Loss	3.2 Loss
Southern Tier	61	32	29 Gain	90.7 Gain
Columbus	58		58 Gain	0
Toronto	56	58	2 Loss	3.5 Loss
Providence	54	43	11 Gain	25.6 Gain
Ft. Wayne	42	39	3 Gain	7.7 Gain
Schenectady	42	49	7 Loss	14.3 Loss
Springfield	34	33	1 Gain	3.0 Gain
Notre Dame	26		26	
Total Membership	4861	4302	559 Gain	13% Gain

Table II

This table shows the net gain and percentage of gain of each chapter in the three groups with the chapters arranged in the order of their net INCREASE IN MEMBERSHIP. As a matter of interest the percentage of gain is again given:

	GROUP I	
Detroit	126 Gain	33.7 Gain
Chicago	52 Gain	13.7 Gain
Pittsburgh	30 Gain	9.4 Gain
New York	29 Gain	10.8 Gain
Boston	11 Gain	4.6 Gain
Philadelphia	17 Loss	4.8 Loss
*Cleveland	92 Loss	22.8 Loss
	GROUP II	
Dayton	132	

*This loss for Cleveland was due to the heavy transfer of members to the new Canton-Massillon, Columbus and Dayton Chapters.

Canton-Massillon	112	
Indianapolis	14 Gain	16.7 Gain
Buffalo	9 Gain	15.3 Gain
St. Louis	8 Gain	9.7 Gain
Cincinnati	0	0
Hartford	3 Loss	2.2 Loss
North-West	3 Loss	5.5 Loss
Milwaukee	4 Loss	3.1 Loss
Golden Gate	4 Loss	3.4 Loss
Syracuse	7 Loss	7.4 Loss
Montreal	11 Loss	13.2 Loss
Lehigh Valley	20 Loss	14.6 Loss
	GROUP III	
Columbus	58	
Southern Tier	29 Gain	90.7 Gain
Notre Dame	26 Gain	
Tri City	25 Gain	38.5 Gain
Worcester	17 Gain	28.8 Gain
Los Angeles	16 Gain	22. Gain
Providence	11 Gain	25.6 Gain
New Haven	10 Gain	14.1 Gain
Washington	4 Gain	5.9 Gain
Ft. Wayne	3 Gain	7.7 Gain
Springfield	1 Gain	3. Gain
Schenectady	7 Loss	14.3 Loss
Rockford	2 Loss	3.1 Loss
Rochester	2 Loss	3.2 Loss
Toronto	2 Loss	3.5 Loss

Table III

This table shows the arrangement of all of the old chapters and groups of the Society with the group divisions disregarded and arranged in the order showing the net gain in membership in comparison with all of the other chapters and groups of the Society:

November 1926 to November 1927

New Groups

1. Dayton	132
2. Canton-Massillon	112
3. Columbus	58
4. Notre Dame	26

Old Groups and Chapters

1. Detroit	126 Gain	5. Southern Tier	29 Gain
2. Chicago	52 Gain	6. Tri City	25 Gain
3. Pittsburgh	30 Gain	7. Worcester	17 Gain
4. New York	29 Gain	8. Los Angeles	16 Gain

9. Indianapolis	14 Gain	21. Toronto	2 Loss
10. Boston	11 Gain	22. Hartford	3 Loss
11. Providence	11 Gain	23. North-West	3 Loss
12. New Haven	10 Gain	24. Milwaukee	4 Loss
13. Buffalo	9 Gain	25. Golden Gate	4 Loss
14. St. Louis	8 Gain	26. Syracuse	7 Loss
15. Washington	4 Gain	27. Schenectady	7 Loss
16. Ft. Wayne	3 Gain	28. Montreal	11 Loss
17. Springfield	1 Gain	29. Philadelphia	17 Loss
18. Cincinnati	0 Gain	30. Lehigh Valley	20 Loss
19. Rockford	2 Loss	31. Cleveland	92 Loss
20. Rochester	2 Loss		

Table IV

This table shows all of the old chapters and groups of the Society arranged in the order of a percentage of increase or loss of members for the past year.

1. Southern Tier	90.7 Gain	17. Springfield	3.0 Gain
2. Tri City	38.5 Gain	18. Cincinnati	0
3. Detroit	33.7 Gain	19. Hartford	2.2 Loss
4. Worcester	28.8 Gain	20. Milwaukee	3.1 Loss
5. Providence	25.6 Gain	21. Rockford	3.1 Loss
6. Los Angeles	22. Gain	22. Rochester	3.2 Loss
7. Indianapolis	16.7 Gain	23. Golden Gate	3.4 Loss
8. Buffalo	15.3 Gain	24. Toronto	3.5 Loss
9. New Haven	14.1 Gain	25. Philadelphia	4.8 Loss
10. Chicago	13.7 Gain	26. North-West	5.5 Loss
11. New York	10.1 Gain	27. Syracuse	7.4 Loss
12. St. Louis	9.7 Gain	28. Montreal	13.2 Loss
13. Pittsburgh	9.4 Gain	29. Schenectady	14.3 Loss
14. Ft. Wayne	7.7 Gain	30. Lehigh Valley	14.6 Loss
15. Washington	5.9 Gain	31. Cleveland	22.8 Loss
16. Boston	4.6 Gain		

BOSTON CHAPTER

"Oxygen—The Wonder Worker", an educational film produced by the Air Reduction Sales Company in co-operation with the U. S. Bureau of Mines, was the feature of the December meeting of the Boston Chapter held at Massachusetts Institute of Technology, Cambridge, on Friday, December 2, 1927. This film, which consists of four reels, shows how liquid air is made; why it is possible to separate the gases of the air; how oxygen is extracted from the atmosphere; how the high temperature (6300 degrees Fahr.) of the oxyacetylene flame is produced; how carbide is made and acetylene gas generated; how iron, steel, copper, brass, aluminum and other metals are welded; how steel and cast iron are cut; how the oxyacetylene torch is adapted to mechanical cutting and welding; and how welding and cutting operations of great econom-

ical value are performed in some of the country's important industrial plants and railroad shops.

Many people have marvelled at the ease with which the oxyacetylene torch has helped reduce several of the country's battleships to scrap metal. Many more have wondered how steel is cut by oxygen and how oxygen itself can be extracted from the air. The answers to these and many other questions relating to the commercial production and use of oxygen were shown.

Previous to the showing of the film G. E. Harcke, industrial engineer, Airco-Davis Bournonville Welding Institute, Jersey City, N. J., gave a short engineering talk on the oxyacetylene process, after which he, with the assistance of J. F. Calahan, demonstrated what can be done with liquid oxygen. During the demonstration he changed full bloomed roses into porcelain flowers which broke into fragments when dropped on the floor, he turned hot-dogs into stone ones and made marbles out of Cape Cod cranberries.

Dinner was served, as usual, in Walker Memorial at 6:15 p. m., some seventy members attending. At the evening meeting there was an attendance of 140.

H. E. Handy.

THE BOSTON CHAPTER METALLURGICAL COURSE

First Lecture. The Boston Chapter Educational Course in Metallurgy was launched on October 14 at the Massachusetts Institute of Technology. The total enrollment is 104, of which 80 are active members of the Chapter, the balance being the representatives of the Sustaining Members. The lecturer, Dr. George B. Waterhouse, Professor of Metallurgy at Technology, was at his best and anybody who has attended the meetings of the Boston Chapter knows what that means. The first lecture covered the "Raw Materials of the Iron Industry," and a complete set of notes, prepared by Dr. Waterhouse, was distributed to each person, making it unnecessary to take any notes during the lecture.

Iron ores were first discussed and after a series of slides had been shown he gave a description of the most important ones, including magnetite, red hematite, brown hematite, and carbonate ores, giving the location of important deposits and the characteristics and treatments of each. In his discussion of fluxes, he explained the action of fluxes and slags on the metal being treated, giving the special uses to which each flux is put. Regarding the ferro-alloys, he told of the importance of ferromanganese in the blast furnace, cupola and steel plant and touched briefly on the manufacture and uses of ferrochromium, ferrosilicon, ferrotungsten, etc. Samples of the ores, fluxes and ferro-alloys were on exhibition during and after the lecture.

Second Lecture. The second lecture by Dr. Waterhouse, on October 21, covered a complete discussion of the "Fuels of the Iron Industry," given under three headings, solids, gases and liquids. After giving a brief talk on the past and present uses of wood, charcoal and anthracite coal, a very thorough discussion of the most important fuel of the industry, bituminous coal, was given. The manufacture of metallurgical coke, both bee-hive and by-product, was described. Regarding gaseous fuels, the relative heating value of natural gas, producer gas, coke-oven and city gas, and the methods

of production of each, were explained. The manufacture and uses of the liquid fuels, fuel oil and coal tar, and also the relation of electricity to the industry were covered briefly.

Third Lecture. The "Blast Furnace and Its Products" was the subject of the third lecture of the Course, on October 28th. Dr. Waterhouse began his talk by giving statistics regarding the number of blast furnaces in operation and their geographical location. With the aid of slides he gave a complete description of the blast furnace, stoves, power plant, cast-house and pig machines, and gave figures showing the amount of raw materials necessary to make a ton of pig iron. The quantities of by-products, slag, flue dust and gas, and their uses, were explained in detail. The speaker stated that the reactions taking place in the blast furnace are not thoroughly understood except that the reaction is that of reduction with CO as the reducing agent. Tables were shown giving the analysis of typical pig irons and the quantities of each grade produced each year.

Fourth Lecture. The subject of the fourth lecture, held on November 4 was "The Iron Foundry," with Dr. Waterhouse as lecturer. Dr. Waterhouse, in speaking of "Direct Castings," stated that the most ambitious attempt to utilize direct metal is the method worked out at the River Rouge plant of the Ford Motor Co., and he gave a complete picture of the Ford process.

The cupola and its operation was carefully explained and figures given to show the amount and kinds of metal, flux and coke necessary to produce a ton of gray iron. Blast pressures, coke ratios and cupola capacities were also given.

The composition of foundry pig irons, of cast iron for different sections, methods of calculating mixtures and losses in the cupola concluded the fourth lecture of the Course.

Fifth Lecture. The Boston Chapter Metallurgical Course entered its second month on Friday, November 11, 1927, when Dr. George B. Waterhouse, Professor of Metallurgy at Massachusetts Institute of Technology described the Manufacture and Properties of Malleable Cast Iron and Wrought Iron. Taking up the subject of American malleable cast iron, or black-heart malleable, described the growth of the industry in this and other countries. Descriptions of both the air-furnace and the cupola methods were given. The annealing process was thoroughly explained after which the composition of the castings, the methods of cleaning and the physical properties were given.

Stating that wrought iron is one of the purest commercial forms of iron and that its most valuable properties are its ease of welding and its resistance to atmospheric corrosion, Dr. Waterhouse proceeded to describe, with the aid of many slides, the manufacture of wrought iron by the puddling process. He also discussed mechanical puddling by the Roe process and the Aston process.

Sixth Lecture. The subject of the sixth lecture given on November 18 was Acid Bessemer Steel, nearly the whole period being taken up with slides showing the Bessemer and open-hearth steel practice. The fine collection of slides, the personal property of Dr. Waterhouse, covered the de-

sign and operation of Bessemer converters and open-hearth furnaces, including preparation of the furnaces, charging, melting, tapping, pouring, duplexing, etc. At the conclusion the speaker described briefly the early history of the acid Bessemer process, the growth of the industry, the composition of the blown metal and the finished steel and, finally, its properties and uses. The basic Bessemer, as used in foreign countries, and the duplexing process were briefly covered.

Seventh Lecture. Basic Open-Hearth Steel was the subject of the seventh lecture given on November 25. After giving the history of the development of the process, statistics were given showing the distribution of production in this country. Dr. Waterhouse, proceeded to describe, step by step, the making of a typical heat of 0.20 per cent carbon structural steel in a stationary furnace. Several modifications of the basic open-hearth process were also mentioned, including the duplex process which is a combination of the acid Bessemer and the basic open-hearth, and also the Talbot process used in some plants employing 100 per cent pig. Concluding his talk the speaker stated that basic open-hearth steel is made in all standard grades, embracing practically everything except the highest grades of tool and alloy steels.

Eighth Lecture. "Acid Open-Hearth, Crucible and Electric Furnace Steels" was the subject of the eighth lecture given on December 2, just previous to the regular meeting of the chapter. After a number of slides showing installations of the three methods of steel making, Dr. Waterhouse hit the high spots of each process, giving statistics regarding the relative production of each and also their characteristics and uses. Steel castings, their manufacture and treatment, were also discussed. *H. E. Handy.*

BUFFALO CHAPTER

The November meeting of the Buffalo chapter was held on November 17, at the Hotel Statler, and the meeting was called to order by chairman Mr. McCarthy at 8:30 p. m.

The speaker, H. Korp, of the Leeds and Northrup Co., was introduced and his talk, "The Heat Treatment of Steel", was one of the most practical lectures the chapter members have heard for some time.

A very interesting discussion followed, and after adjournment a buffet lunch was served to about 35 members and guests.

F. L. Weaver.

CHICAGO CHAPTER

The November meeting of the Chicago Chapter A. S. S. T. was held Thursday, November 10 at the City Club, 130 members and guests were present for dinner. After dinner the secretary read a number of letters received from officers and members of various Chapters expressing their deep regret and sympathy to the Chicago Chapter because of our loss due to the death of A. G. Henry. (Following the reports of the November and December meetings of the Chicago Chapter is printed in full the memorial address to Arthur G. Henry given by Samuel M. Havens at the regular October meeting of the chapter.—Editor).

James P. Gill, chief metallurgist of the Vanadium Alloy Steel Company gave a very interesting paper on "Tool Steels—their Chemical Composition and the Effect of Alloys on their Constitution and Heat Treatment". Mr. Gill gave a fundamental talk of what can be expected in the way of physical properties and quality of steel by additions of various alloying elements, also discussed the subject of alloys and their effects on the constitution and heat treatment of alloy tool steels from a very elementary standpoint, covering their entire field in a very systematic manner, giving a complete picture what to expect in certain alloy steels. Mr. Gill also had a number of slides showing the effect of alloys on the microstructure, and also had several charts showing the great number of alloy steels available with their specific chemical analyses. At the close of Mr. Gill's paper A. T. Clarage brought up the question of economies of the alloy tool situation, especially regarding the higher priced tool steels vs. cheaper tool steels which was interestingly discussed.

The Chicago Chapter held its regular monthly meeting for December at the City Club Thursday evening December 8. The dinner preceding the meeting was well attended.

After several announcements were made by Chairman Barker, he introduced the speaker Claud S. Gordon, president of the company bearing his name and a member of the Chicago Chapter. Mr. Gordon gave a detailed and interesting talk on "Pyrometry and Automatic Temperature Control in Industry," he reviewed pyrometry from the first development up to the present time, and had a number of slides showing many modern installations of automatic temperature control on all types of heating equipment. Mr. Gordon stressed the importance of proper installation of temperature measuring apparatus and the necessity of proper maintainencé of the equipment in service.

After Mr. Gordon had closed, a very interesting discussion followed, many questions being discussed and opinions expressed bearing upon the various phases of the subject. *A. M. Steever.*

EULOGY TO ARTHUR G. HENRY

By Samuel M. Havens

It is to be expected that the American Society for Steel Treating, and, particularly its Chicago Chapter, will pause at the announcement of the death of Arthur G. Henry. We are compelled to pause because the news stuns us. There is the overwhelming feeling of great loss to our Society and to this Chapter, and of deep personal sorrow. Naturally, we wonder how it is ever going to be possible to fill his place.

Even if we were not forced by the shock of his passing to come to a stop, it would be fitting that we should do so out of respect to his memory and in recognition of the efficient, unselfish work that he has always performed for our Society.

Arthur G. Henry was born in Wales some years ago—how many, it does not matter, because to those who knew him he was the embodiment of perpetual youth. After some years of apprenticeship in the iron and steel works of Wales he continued his metallurgical education at the University of Bonn.

Later he was assistant chemist of a large steel plant in the Ruhr valley of Germany. In 1896 he came to this country and was employed in the research laboratory of the Illinois Steel Company at South Chicago. Later he represented in this district the Vanadium Alloys Steel Company. In 1920 he organized the Perfection Tool Hardening Co., of Chicago, and largely through his efforts that company built up a splendid business. In 1926 he transferred his interests to the Danly Machine Specialties, Inc., Chicago, with which organization he was associated at the time of his death.

Notwithstanding his success as a metallurgist and in the business world, he will be remembered longest because of the fact that in 1918, when this Society was young and struggling, he conceived the idea of holding, in connection with its annual convention, a National Steel Exposition. The plan was his, and his alone, but it was no easy task to carry it out. Our Organization was then lacking in funds, and, to embark upon an enterprise involving the expenditure of many thousands of dollars, called for much healthy optimism, some enthusiasm and endless energy. All these qualities Arthur Henry possessed, and he was able not only to convince the officers of the advisability of his plan, but to help them very largely in carrying it out.

The 1919 Exposition, held in Chicago, was a splendid affair in point of size and quality of exhibits. We were very proud of it then. We ought to be even more proud of it now, because, whereas it has been exceeded in size and bettered in quality every year, nevertheless, that 1919 Exposition, conceived and energized by Arthur Henry, was the seed of the splendid expositions and wonderful conventions that we hold today. I have often thought, as I have watched Arthur Henry walk through the aisles of our expositions of later years, how proud he must feel and how glad he must be, not only for himself but for the rest of us, that he was the father of the idea that has meant so much to our organization, and that all these splendid exhibits grew from his conception and from his energy and ability in making the first exposition such a pronounced success. Our Society recognized what every one of us felt when, in 1926, it conferred upon him the title of Founder Member. In doing so the Society honored itself as well as Arthur G. Henry.

But he was not content with one magnificent effort for the Society that he loved. Every one knows that he was working continuously for it right up to the time of his death. Many of his efforts, furthermore, were of the kind that were little known by those who were not connected with the Society in an official capacity. Generally speaking, few of us appreciated how much time and effort he devoted to telling of the benefits of our organization to those who ought to become its members. It is fair to say that for several years a large portion of the work of increasing the membership of the Chicago Chapter has been done by him. His work as Secretary-Treasurer of this Chapter is too well known to require comment, and if any of us have a regret, it is that we allowed him to do so much of the work and helped him so little.

It must be borne in mind that Arthur Henry's devotion to our Society and to this Chapter was always unselfish. His efforts in their behalf brought him no monetary return, either directly or indirectly. He worked because

he believed that the Society was filling a useful field and that the world would be better if the Society prospered. It may be truthfully said of him that the promotion of the best interests of the American Society for Steel Treating was his life work. It is difficult to describe in words his attitude toward our organization. To state that it was genuinely unselfish is not enough. It were better expressed by saying that he was enthusiastically devoted to its welfare.

The personality of Arthur Henry was one that appealed to us all. We rejoiced to have him as a friend. He knew how to be a friend because he was thoughtful, unselfish, honest and manly. You and I will always carry a picture of his happy face, will recall the sparkle of his eye, and hear anew his cheery voice. These things not even death can take from us. You and I will be better because Arthur Henry lived.

Because we have ourselves the sense of deep personal sorrow and great loss, we naturally feel at this time a real sympathy for his wife and the relatives who survive. To them we can say sincerely that the memory of his splendid example and of his delightful personality must always be a comfort.

When we first heard the news of his passing, I suppose there came to all of us immediately the thought—what shall we do without him? That is but natural. He has done so much for this Society and this Chapter that it seems almost impossible to fill his place. Yet I am sure that Arthur Henry would be the last to countenance such a thought. He did not devote himself untiringly and unselfishly to this organization with the idea that when he passed on he would leave a void that could not be filled. Arthur Henry worked not for himself but for the Society, and it would be a poor compliment to his work if we could not say he laid for us a broad and firm foundation on which we could build a superstructure that would realize to some extent his dreams. No, we must carry on! Others must be found to assume his duties. We must catch his enthusiasm and his devotion, and the burdens that he carried must be shifted to many shoulders. Our great, young, vigorous Society must go forward and our splendid Chicago Chapter must continue in the lead as always!

Being human, we can but feel the sense of loss and sorrow, but this is no time for mere lamentation. Rather we must consider ourselves fortunate that Arthur Henry lived and that he worked so long and so unselfishly with us and did so much for us. The death of such a man is a triumph.

Good old Arthur Henry, loyal, unselfish and devoted, a Founder of the American Society for Steel Treating, we salute you—outward bound!

CINCINNATI CHAPTER

The November meeting of the Cincinnati Chapter was held at the Engineer's Club on Thursday evening, November 3, 1927. Among those present as guests of the chapter were J. W. Beck, director of research of the American Rolling Mill Company; Dr. A. S. Cushman of New York, John R. Cain of Washington, and Dr. Hayes of Iowa State College.

After calling the meeting to order Mr. Lucas turned the chair over to J. Hunter Nead, national director of the society. Mr. Nead dispensed with

the ordinary routine of business, and introduced Dr. Zay Jeffries, the speaker of the evening.

Dr. Jeffries discussed the orientation of the crystals of alpha iron in both slowly cooled and in quenched steels as revealed by X-ray analysis. He also described some interesting experiments in which the change in hardness and volume of samples of quenched steel after either aging at room temperature or quenching in liquid air were studied. He showed how these experiments threw new light on the nature of the decomposition products of austenite, and furnished further evidence in favor of the slip interference theory of hardening.

Mr. Nead next called on Dr. Cushman who spoke briefly on the amazing progress being made in metallurgy today, and of the many new problems opening before us. He also emphasized the debt that scientists of this century owe to such pioneers as Michael Faraday and Sir Humphry Davy.

The December meeting of the Cincinnati Club was held at the Engineer's Club on Thursday evening, December 1, 1927. Dr. John A. Mathews vice-president of the Crucible Steel Company of America, and honorary member of the American Society for Steel Treating addressed the chapter on the Effect of Chromium on Iron and Steel.

Dr. Mathews began by tracing the early history of alloy steels, showing how at first they were used almost exclusively for ordnance, and owe their rapid development to the coming of the automobile. He next discussed the more common alloying elements found in steel explaining briefly the specific effects of each. Turning to chromium steels he emphasized the wide range of composition of these alloys pointing out that the carbon content might run as high as 3 per cent and the chromium content as high as 60 per cent. He next classified the various chromium steels pointing out the special properties and fields of usefulness of each class. He closed by explaining some interesting points involved in the heat treatment of certain chromium steels, which had been brought out during his own researches on retained austenite.

Ray O. McDuffie.

CLEVELAND CHAPTER

The regular meeting of Cleveland Chapter was held Friday evening, November 18, in the Engineering Society Rooms in Carnegie Hall. The largest attendance of the year turned out and over thirty members were present at dinner.

Reports from the chairmen of different committees were heard and approved. Dr. Oscar E. Harder, professor of metallography at the University of Minnesota was the speaker.

In his talk Dr. Harder covered his subject in a broad and practical manner. He brought out the importance of the application of metallography to the industry and pointed out the tremendous need of development along this line. He stated that metallography only constituted a small percentage of engineering courses of the various universities today and that a large number of the present metallographists had received their training since leaving the universities. The fact of the importance of this science to quality production in the commercial field is one of the major factors in the success or failure of manu-

acturers today. The point was that plants without the aid, knowledge and equipment of the metallographist could not hope to meet the quality competition of other plants so equipped.

Dr. Harder also pointed out the really small number of combinations of the different alloys which have been investigated to date, which point was to emphasize the great field of development and research which is open to the metallographist.

J. S. Ayling.

COLUMBUS CHAPTER

The Columbus Chapter held its regular monthly meeting Tuesday evening, November 15, 1927, at the Fort Hayes Hotel. A dinner preceded the regular meeting which was attended by a goodly number.

The speaker of the evening was J. P. Gill, metallurgist of the Vanadium Alloys Steel Company of Latrobe, Pa. He delivered a very interesting talk on the Chemical Composition of Tool Steel and the Effect of Alloying Elements.

Mr. Gill gave the characteristic properties imparted by various alloying elements, manganese, nickel, chromium, vanadium, tungsten, molybdenum, cobalt and silicon. He also discussed the various compositions of different high-speed steels.

The talk was very well received and Mr. Gill was given a rising vote of thanks.

The next meeting was announced for January 17, 1928, at which time the Norton Company movie "The Age of Speed," will be shown.

G. D. Moessner.

DAYTON CHAPTER

The first nonferrous session of the Dayton Chapter was held at the Engineer's Club, Tuesday evening, November 22, 1927. Fifty members met for dinner at 6:30. R. L. Hankinson, chief of the physical testing laboratory and wood branch, U. S. Air Corps, Wright Field, was the dinner speaker. Mr. Hankinson's specialty is wood and he gave a very interesting informal talk on this well known but little appreciated structural material. Mr. Hankinson traced the history of wood as a first aid to civilization from the ancient days when it was used for cannon and tools to the present where it is used not only as a structural material but for the manufacture of paper and "rayon" or artificial silk. He stressed the fact that wood, due to its beautiful grain, is the only material which readily lends itself to artistic expression. The result is that wood is used almost exclusively for furniture and interior decoration. Probably for this purpose it will never be supplanted by any other material. A fact which surprised many of the steel men present was the statement that on a strength-weight basis, wood is stronger in tension and as strong in compression as either carbon steel or duralumin. In other words, a one pound bar of wood is stronger than a one pound bar of either carbon steel or duralumin. Mr. Hankinson stated that this strength-weight advantage had been made use of for years in airplane construction.

The regular meeting was held in the Auditorium at 8 o'clock. R. R. Kennedy, metallurgist of the National Cash Register Co., gave the educational feature "Austenite", illustrated by typical photomicrographs. One hundred members were present.

The principal talk of the evening was given by W. H. Bassett, technical superintendent and metallurgist of the American Brass Co., Waterbury, Conn., on "The Uses and Application of Copper and Copper Alloys". Mr. Bassett's talk was profusely illustrated by slides. He discussed copper and its alloys from melting and refining the raw copper, to the properties and uses of the finished material. He described electrolytic and Lake copper, the rolling of the ingots and the properties of the pure metal after being drawn into wire. Especially interesting was the discussion of the effects of various impurities such as silver, copper oxide and others on the properties of the metal, and the methods of deoxidizing the copper.

In taking up the copper alloys, Mr. Bassett described the melting practice, the constitution of brass, and the uses of the various brasses from the 90 copper-10 zinc, to the 60 copper-40 zinc; and the copper-zinc-lead alloys.

Following this was a discussion of the corrosion resistance of the copper-zinc alloys and the season cracking of brass. The speaker gave the causes of season cracking and named the alloys in which this defect did not occur.

The discussion of the brasses was followed by a description of the constitution, uses and properties of the copper-nickel alloys, the copper-tin alloys, and the copper-silicon and copper-silicon-manganese alloy. *F. T. Sisco.*

DETROIT CHAPTER

The November meeting of the Detroit Chapter was held November 21 in the General Motors Building. An interesting dinner talk was given by Judge W. H. Heston, of Yost's famous "point-a-minute" team, on his earlier football memories.

At eight o'clock O. L. Pringle of the Pittsburgh Crucible Steel Co. spoke on manganese steel. The use of manganese in steel dates back to the start of the Bessemer process and even then was the subject of much debate. Without manganese the Bessemer process could not have survived, and the use of manganese as a deoxidizer has become so much the accepted thing that it is difficult for people in general to comprehend and view it as the producer of a true alloy steel in slightly higher than the usual percentages. At present no metal will take the place of manganese in the steel industry.

In further developing his subject, Mr. Pringle went into the manufacture of steel in general and manganese steel in particular. The users of manganese steel as we know it today were just the railroads, who used it in rail parts, car parts and locomotive axles.

Common manganese steels are—(a) 0.30 to 0.40 per cent carbon and 1.60 to 1.90 per cent manganese (b) 0.10 to 0.20 per cent carbon, 1.20 to 1.50 per cent manganese, this latter used for case hardened parts.

Mr. Pringle closed his paper with charts comparing the 3100 series and 2300 series of steels with the 1.60 to 1.90 per cent manganese steels. In these tables the physical properties were all quite similar.

The second speaker to discuss the subject was R. B. Schenck of the Buick Motor Company, a large user of manganese steel. Mr. Schenck pointed out that, while all alloying elements have their own special applications and limitations, manganese seemed to be similar to nickel and chromium equaling

the latter in influence and being three times greater than the former. Manganese not used to combine with sulphur is present as carbide and in solid solution. Manganese appears to have little effect on the critical points in heating but lowers them greatly on cooling. The steel as received from the mill, if properly made, is as free, or freer from defects than other alloy steels. The machinability compares with the low chromium-nickel series except in the special high sulphur type which is as good or better than 1120 S. A. E. in this respect.

These high sulphur carburizing steels are coming more and more into play. Carbon varies from 0.10 to 0.25 per cent, manganese 1.00 to 1.75 per cent and sulphur from 0.075 to 0.150 per cent. With proper heat treatment a hard case and tough core are obtained. *J. G. Gagnon.*

FORT WAYNE GROUP

The November Meeting of the Fort Wayne Group of the American Society for Steel Treating was held Thursday, November 17, 1927 at the Y. M. C. A. and was preceded by a dinner at which W. E. McGahey acted as toastmaster. Entertainment was furnished by the Cafaro Family Trio.

At this meeting the Fort Wayne Group was honored by the presence of H. Kenneth Briggs, assistant secretary of the national organization. Mr. Briggs gave an interesting talk on the aims, ideals and history of the A. S. S. T., touching upon some of the points of particular interest to the prospective members, explaining the cost of issuing the various publications which the Society publishes.

After Mr. Briggs' talk, the speaker of the evening, Howard W. Dunbar, grinding expert, was introduced by the chairman. Mr. Dunbar gave a very interesting talk on "Grinding and Its Service to the World."

Mr. Dunbar's paper pointed out that in the mind of the layman, a grinding wheel is very insignificant but in reality it is a very important tool which is used either, directly or indirectly, in the manufacture of almost all of the articles we come in contact with daily. He described the manner in which the various materials are mixed and introduced into the electric furnace for the manufacture of artificial abrasives. Then how these abrasives are formed into grinding wheels which are used in some manner in practically every industry. *J. A. Hansen.*

GOLDEN GATE CHAPTER

The November meeting of the Golden Gate Chapter was held at the plant of the Caterpillar Tractor Company at San Leandro, California, on the evening of Wednesday, November 16. The dinner, well prepared by the ladies of the Presbyterian Church, was served in the church dining room. Following the dinner the meeting was called to order by Chairman Dr. W. J. Crook, who, on account of the lateness of the hour, was not able to discuss some of the latest European metallurgical achievements recently visualized while abroad.

Dr. Crook spoke briefly and enthusiastically on the Junior Scholarship plan as proposed by A. C. Naish of the heat treating department of the Caterpillar Tractor Company.

C. O. Perrine next showed several movies of the Caterpillar in action. The "Cat" was seen in the harvest field, logging camp, at road building and ditch digging; again leveling sand dunes in western San Francisco, and making fire trails in the high Sierras. Conspicuous by its absence however, was the picture of the Caterpillar towing a highway bus from Melrose to San Leandro. After the showing of the pictures, the next in order was plant inspection. The members and guests were divided into groups of six or eight and with a well-versed guide, conducted through the plant where this efficient and world renowned "tool" is built.

While many felt that "hours" could be well spent with profit and pleasure, nevertheless in the two hours alloted much was seen to cause praise and admiration of this distinct and progressive western enterprise. As a body of steel treaters, it was realized that, without our art and science of steel treating, many of today's industrial achievements of the Caterpillar tractor would not be possible.

The chapter is highly appreciative of the courtesy of the officers and employees of the tractor company in general, and C. O. Perrine in particular, under whose immediate direction the visit was arranged and concluded.

The dinner was attended by 78 while more than 100 were present at the meeting and plant inspection. *S. R. Thurston.*

LOS ANGELES CHAPTER

The November meeting of Los Angeles Chapter was held November 10, at the banquet room of the Los Angeles Creamery Company. The meeting opened promptly at 6:30 p. m., with an excellent dinner. There were eighty-five members and guests present at the dinner.

Immediately following the dinner, Carl Fromme, of Axelson Machine Company, chairman of the convention committee, made a report to the chapter on the activities and accomplishments of the committee.

After the report of the convention committee, Wade Hampton, our chairman, introduced the speaker of the evening, James H. Knapp, president of the James H. Knapp Engineering Company. Mr. Knapp read a paper on "Problems in Furnace Design, and Heat Treatment." The paper was unusually interesting, and covered the subject thoroughly.

This meeting was a regular movie treat. We were fortunate in having for this meeting two four reel pictures. The first shown was the picture, "Electric Heat in Industry", made and furnished us by the Detroit-Edison Company. The picture showed heat treating plants in the East, and types of furnaces used in some of the large automobile plants, such as General Motors, Dodge and Ford.

The next picture was "The Age of Speed" made and furnished us by the Norton Grinding Wheel Company of Worcester, Mass. The picture not only shows the process of manufacture of the wheels themselves, but shows the wheels in practice, grinding large steel rolls, crankshafts and many other applications of grinding.

After these two industrial pictures, H. St. Clair Knight, a picture director of Hollywood, showed two 16mm comedies, that were enjoyed by the members.

Bill Farar, our membership chairman, was very much "on the job", and several new memberships are on their way to Cleveland.

The meeting was one of the most pleasant and profitable of the year.

H. V. Ruth.

NEW YORK CHAPTER

About 300 were present at the meeting and 77 at the dinner preceding the meeting of the New York Chapter on November 14. This was the largest meeting ever held by this chapter, invitations were sent to all the civil engineers in the Metropolitan District.

The general subject was "Strong Steel for Modern Long Span Bridges."

From 8:00 to 8:30, Leon S. Moisseiff, consulting engineer, New York, gave a paper on "The Designer's and Owner's Requirements." Mr. Moisseiff is the advisory engineer for the Port of New York Authority, under whose direction the new Hudson River Bridge is being built from Washington to Fort Lee.

Following this talk, several authorities spoke showing how these requirements are being met.

8:30 to 8:45—"Manufacture of Acid Steel for Suspension Cables," by H. C. Boynton, metallurgist, John A. Roebling's Sons Co., Trenton, N. J., builder of the Brooklyn Bridge and many notable structures since.

8:45 to 9:00—"Wire Drawing and Heat Treatment," by A. V. deForest, research engineer, Page Steel & Wire Co., Bridgeport, Conn., which made the wire cables for the Philadelphia-Camden Bridge.

9:00 to 9:15—"Manufacture of Structural Silicon Steel," by H. T. Morris, metallurgist, Bethlehem Steel Co., Bethlehem, Pa., which made and erected the steel in the towers of the Philadelphia-Camden Bridge.

9:15 to 9:30—"Nickel Steel for Long Span Bridges," by Clement E. Chase, of Modjeski & Chase, consulting engineers, Philadelphia. Mr. Chase was principal assistant engineer on the Philadelphia-Camden Bridge.

It was shown that the aim of the bridge builder is to reduce the weight of long spans by using high strength materials which permit higher intensities of stress. Progressively greater strength has been specified in bridge building. This increasing demand has been met by properly selecting the materials and refining the process. Nickel steels have also been used to a large extent and considerable tonnages of silicon steel are used in this type of construction. The subjects of heat treated eyebars, heat treated wire, acid steel for suspension cables, the economic manufacturing of special steels were also discussed. *T. N. Holden.*

NOTRE DAME GROUP

The December meeting of the Notre Dame group of the American Society for Steel Treating was held at the Morningside Club, in South Bend, Thursday night, December 8.

A chicken dinner was served at seven o'clock, and the business meeting was held immediately after.

The greater part of the time was given over to the discussion and adoption of a constitution, and set of by-laws.

The entertainment was furnished by Wayne H. Ewing, who reviewed the paper, "Deterioration of Structural Steels in the Synthesis of Ammonia," by J. S. Vanick, which appeared in the August 1927 number of the TRANSACTIONS. After the more serious part of the meeting was over the members furnished lighter entertainment in the way of music, singing, recitations, and special tricks.

After adjournment the members fared forth into the blinding snowstorm, to find their various ways home. *Robert E. Bannon.*

RHODE ISLAND CHAPTER

The November meeting of the Rhode Island Chapter turned out to be a very interesting one. The meeting was held in the Engineering Laboratory of Brown University and the speaker of the evening was Professor William H. Kenerson, professor of mechanical engineering at Brown University.

Professor Kenerson spoke on the various methods and types of machines for making hardness tests, describing quite fully the Brinell, Rockwell hardness tester, and the Scleroscope. W. Lewis of Tinius Olsen & Sons, Philadelphia, Pa., described the workings of the Herbert Pendulum Hardness Tester.

Test specimens were submitted for comparative hardness tests and the discussions prompted by Professor Kenerson were very lively, taking up so much time that the microscopes and photomicrographic apparatus, which were intended to be shown, had to be omitted.

C. H. Myrick of our own chapter, who has done considerable microscopic and research work, had on exhibition a hardness comparator for testing the abrasion resistance properties of metals, a very interesting device.

The meeting was exceptionally well attended, there being at least one hundred and twenty-five members and guests present. The next meeting will be held December 21 at the Providence Engineering Rooms, where S. C. Spalding of the Halcomb Steel Co., will speak on the subject of carburizing.

E. G. Peterson.

ROCHESTER CHAPTER

The third regular meeting of the Chapter was held November 14 at the Hotel Osburn. The meeting was preceded by the usual informal dinner at which twenty members and visitors were present.

Following the dinner all retired to the assembly hall where an attendance of thirty-two was noted.

After a short business session Mr. Wattel, vice chairman, in the absence of our chairman, introduced as speaker of the evening, J. R. Morris, assistant metallurgical engineer, Central Alloy Steel Corporation, whose most interesting subject was entitled "Some Factors Concerning the Selection of Alloy Steels".

Mr. Morris dealt with the various types of molybdenum, chromium-vanadium and other alloy steels and illustrated his paper with a number of very interesting slides, showing the different processes of steel making, photomicrographs, etc.

After some discussion the meeting adjourned with a rising vote of thanks for the speaker.

H. J. LeClaire.

SCHENECTADY CHAPTER

The second meeting of the series being devoted by the Schenectady chapter to the subject of the "Machining of Metals" was held on Tuesday evening, November 15, in the Rose Room of the Twentieth Century Lunch Room. The committee in charge was very much pleased at the interest shown by the large attendance of members and guests who gathered on that evening to hear A. W. Merrick, metallurgist, General Electric Co., give his talk on "Recent Tests On Various Brands of High Speed Steel."

The technique involved in carrying out the tests was described in detail, particularly the "Taylor Breakdown Test". Conditions were critically examined, to eliminate variations that sometimes invalidate tests of this nature.

The data obtained was interpreted and the implications pointed out. The importance of heat treatment as one of the principle variables that would affect the results was stressed.

The importance and value of Frederick W. Taylor's work in establishing the empirical laws that govern the relationship of speed and tool life was emphasized. The paper was of interest alike to metallurgist, heat treaters and those interested in machine shop practice and was essentially a practical rather than a theoretical presentation of the subject.

The next meeting of the Chapter will be held on Tuesday evening, December 20 at which time we will hear A. H. d'Arcambal, metallurgist, Pratt & Whitney Co., on "Machinability".

James Taylor.

ST. LOUIS CHAPTER

The 70th regular monthly meeting of the St. Louis Chapter of the A. S. S. T. was held Friday evening Nov. 18, 1927, at the American Annex Hotel, with an attendance that was indeed gratifying. The meeting was preceded by an executive committee meeting at the Laclede Gas Building with Mr. Axelson of the Axelson Machine Company, Los Angeles, California as guest.

After a short business session, the guest of the evening W. F. Bretschneider, sales engineer of the Norton Company, St. Louis District was introduced. Our Chapter had the privilege of witnessing the wonderful picture produced by the Norton Company, entitled "The Age of Speed." This film presents a most interesting story, showing how we have passed through the various stone ages, iron ages etc., and today how we are now living in the "Age of Speed."

The picture pointed out the remarkable development which had been made in speed, transportation and communication and how necessary to production grinding wheels and grinding machinery has made these speeds possible.

After the showing of the picture a very interesting discussion followed which brought out questions from the members and guests, which in turn were very ably answered by Mr. Bretschneider.

The meeting was adjourned with a vote of thanks, both to the Norton

Company and to Mr. Bretschneider for their courtesy in affording us a most educational and profitable evening. *C. G. Werscheid.*

SYRACUSE CHAPTER

The regular monthly meeting of the Syracuse chapter was held on November 7, 1927, at the Chamber of Commerce. The usual dinner preceded and the meeting was opened at 8:00 p. m. by Chairman W. R. Frazer. After the reports of the standing committees were submitted, Mr. Frazer introduced as the speaker of the evening, C. B. Calloman, metallurgist for the Allegheny Steel Company of Brackenridge, Pa., who presented a paper on Stainless and Heat Resisting Alloys.

Mr. Calloman introduced his subject with a historical sketch, then followed by describing the manufacturing problems and uses for these steels. In 1916 the Germans and English had developed rustless steels simultaneously; stainless iron with 0.12 per cent carbon and stainless steel with 0.25 per cent carbon had been produced as a result of much experiment. They had discovered that chromium would impart corrosion resisting properties to steel, but only when present to the amount of 11 per cent when the stainless properties begin to be apparent. Working from this lead, the Germans ran a series of experiments using increased amounts of chromium and noting the corrosion resisting properties of each alloy. From 11 to 16 per cent chromium the alloys showed increasing corrosion resisting properties and were heat resisting up to 1450 degrees Fahr. when a slight skin scale forms, impervious to air and closely adhering. When the chromium was increased to 20 per cent the alloy showed a marked improvement in heat resisting properties, while with 25 to 30 per cent the alloy with low carbon content could not be scaled at any temperature under the softening heat. When the chromium exceeded 30 per cent the difficulty in fabricating the steel proved to be far out of proportion to its corrosion and heat resisting properties.

The next step in carrying on these experiments was to introduce nickel to the high chromium alloys in an effort to discover an improved heat resisting alloy and there involved a combination of 7 to 10 per cent nickel with about 20 per cent chromium that was not only heat resisting but also corrosion resisting to a marked extent. This became known as Krupp V 2 A in Germany and Stabrite in England. Another alloy, produced with 22 to 27 per cent chromium and 10 to 12 per cent nickel, proved to be nearly as good as the 25 to 30 per cent chromium alloy, but possessed the advantages of being extremely malleable, resistant to carburizing under normal conditions, and welds made with the same material are not brittle. Metallurgically this metal belongs to the austenitic class.

H. Lyon Day.

TORONTO CHAPTER

The regular meeting of the Toronto Chapter was held on Friday, December 2, in the lecture hall of the Consumer's Gas Co.

The Chapter was fortunate in securing J. H. Friedman, superintendent of the National Machinery Co., Tiffin, Ohio, who gave an address on forging dies illustrated with charts and photographs of various dies and defects due to improper heat treatment. The properties, uses, and heat treatment of chromium and tungsten steels for such work were taken up and special emphasis laid on such important matters as slow preheating. An interesting point in connection with the use of tungsten steel was brought out in the desirability of securing the requisite hardness after passing the point of maximum secondary hardness rather than before reaching that point, in order to avoid the danger of the hot work bringing the die to the point of maximum hardness during operation.

The stream of questions which greeted Mr. Friedman at the close of the paper showed the interest taken in it by the audience.

The next paper will be one by M. J. R. Morris of the Central Alloy Steel Corporation, and is to be given on Friday, January 20.

J. W. McBean.

TRI CITY CHAPTER

On Tuesday night, December 13, the Tri-City chapter of the American Society for Steel Treating, held its regular monthly meeting. Preceding the program of the evening, there was a dinner at the LeClaire hotel, Moline, which was attended by 55 members. After dinner, the program of the evening was given, which consisted of pictures and a talk by H. K. Clark, of the Norton Company, Worcester, Mass. The meeting was held in the auditorium of the People's Power Company at Moline, Ill. Sixty-five members and their friends were present for the program. Mr. Clark's talk, which was illustrated with pictures showed the tremendous advancements that have been made in methods of transportation, communication, etc. Pictures contrasted early developments in railway equipment and in early types of boat locomotion as compared with our modern deluxe trains and steamships. It was then brought out how this progress was more or less dependent upon our modern grinding machines. It was shown that the automobile, for example, depends entirely upon accurate grinding machines for the mass production of crankshafts, cylinder blocks and bearings of all descriptions. Even the newspapers depend upon accurate grinding upon the mechanism of the large presses and line-o-type machines.

Finally the manufacture of these wheels were described and pictures of the large electric furnaces for manufacturing different abrasive material were shown. The carborundum wheels, that we know so well, are manufactured by fusing together a mass of sand and coke at a temperature of around 4000 degrees Fahr. The material as it comes from the furnace is crushed, sized, a suitable binder added, the wheel formed and finally vitrified in long continuous kilns. The aluminum wheels which are used for grinding metals of high tensile strength are manufactured from an ore called bauxite or aluminum oxide. These developments were the result of development of the electric high temperature furnaces. *Geo. A. Uhlmeyer.*

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